ANNUAL REPORT
for
1959

A.R.S. Sedimentation Studies Project
Lincoln, Nebraska

Annual Report
for
Calendar Year
1959

SEDIMENTATION STUDIES

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GENERAL INTRODUCTORY STATEMENT

Calendar year 1959 was another very busy year for this Project. It included very little field work and a correspondingly greater amount of office studies. This is in accordance with the shift in emphasis in our activities from routine sedimentation surveys to a concentration on the analyses of data and the acquiring of special data. This change in emphasis was explained more fully in our Annual Report for 1958.

During the year, this Project made a detailed sedimentation survey only on the Hafner Pond (P-12) in the Newell Project. Our office work was concentrated primarily on a study of sediment distribution in small floodwater retarding type reservoirs and ponds, and on the analyses of sedimentation, precipitation and runoff data collected in the Medicine Creek watershed. We made considerable progress on both studies, as will be explained.

Experimental Outline No. 6, Reservoir Sedimentation Studies, was deleted during the year. Reports on individual reservoir studies will be written as the opportunity is presented. Work under the other five Experimental Outlines will be discussed in greater detail on the following pages.

Verne Dvorak and I are the full time technical personnel assigned. Our forces were bolstered in November by the addition of Elmer Mandrup, an Engineering Aid. We have been in need of this type of assistance and feel that he will be a big help to us.

REPORTS BY INDIVIDUAL EXPERIMENTAL OUTLINES

EXPERIMENTAL OUTLINE NEB-LS-W-1, SEDIMENTATION STUDIES -- NEWELL PONDS AND RESERVOIRS

This is a hydrological and sedimentation study initiated in 1957 on 16 small grassland watersheds in Butte and Meade Counties, South Dakota. These watersheds have various degrees of land use and a variety of soils, slopes and drainage area sizes. The study area is representative of western North and South Dakota, eastern Montana and northeastern Wyoming. Considerable watershed and reservoir data have been gathered and are being collected continually. The sedimentation study is being made primarily to evaluate those characteristics of upstream rangeland watersheds important in sedimentation, and also to develop precedures for estimating gross erosion and sediment yield for this type of watershed.

During the past year we continued with the calculations for the remaining capacity of the twelve reservoirs on which complete sedimentation surveys were made the previous year. As work progressed on the three reservoirs where we only did a portion of the survey work, it was found that the information was not adequate and that the reservoirs would have to be resurveyed. One such resurvey was accomplished the past year, and the other two are planned for next summer. Because of bank erosion, some permanent range ends on one reservoir will have to be moved back. This is also planned for next summer.

Bentonite was found in some of the sediment samples obtained during the course of the reservoir surveys. Its presence will be evaluated.

EXPERIMENTAL OUTLINE NEB-LS-W-2, MEDICINE CREEK WATERSHED INVESTIGATIONS

The Medicine Creek project began in 1951 as a cooperative study by the Soil Conservation Service, Bureau of Reclamation, Geological Survey, University of Nebraska, and Agricultural Research Service. The primary object was to study this large watershed to learn more about sedimentation and runoff, with special emphasis on developing criteria to predict sediment yields, rates of advancement and enlargement of gullies, flow-duration information, and water yield.

The watershed is located in southwestern Nebraska between the Platte and Republican Rivers. It has a drainage area of approximately 690 square miles. Most of the soils are of a deep loess overlying the Ogallala formation.

The drainage system for Medicine Creek is dendritic, but some of its tributaries such as Dry, Curtis, Fox, and Wells Canyon have trellis patterns. The Dry Creek subwatershed has severely entrenched channels which contribute a large part of the sediment yield.

Cultivated land comprises about one-third of the entire area and grazing land the remainder. The percentage of grazing land within the subwatersheds varies from about 50 to 80%.

The following data were collected from 1951 to 1958: precipitation, runoff, sediment load, land use, degree of erosion, soils, field slopes, topography, gully erosion in Dry Creek, and sedimentation yield into Dempcy pond.

During the past year, we continued our analyses, utilizing data as they became available. Work also was started on estimating the long term suspended sediment yields using several procedures.

Precipitation

The precipitation investigations for the study period show that the annual totals were irregular and the average annual amount was below normal. These conditions have a high probability of happening in this geographical area, according to the results from a statistical analysis of Curtis, Nebraska climatological records. The average annual precipitation at Curtis from 1951 through 1958 was 18.82 inches. The average annual precipitation was 19.46 inches for 1930-58, 19.91 inches for 1915-58, and 21.36 for 1894-1958.

The probability of having this large, or a larger, difference in the average annual precipitation for each of these periods compared with 1951-58 is as follows:

Period of Record	Probability Percent
1930-58	58
1915-58	48
1894-58	30

The largest annual precipitation for our study period occurred in 1951 and was measured at 31.61 inches. The computed frequency is once in 14 years. Only four of the 61 years of record exceeded that of 1951. The 1952-1956 period was the driest in 61 years, according to station records. The average annual was 14.55 inches for these five years. In each of the two remaining years of the project, the annual rainfall was close to the long term average.

The analysis of the daily storms shows a similar trend as that found for the average annual precipitation. The largest daily precipitation during the study period was 3.23 inches, which was the sixth largest storm in 48 years. It was computed to have a nine-year frequency.

Runoff

The predominant portion of the total runoff for the eight years was produced in 1951. The drainages with intermittent flow, Dry and Brushy Creeks, had 63 and 35 per cent, respectively, of their total flow occurring in that year. The perennial streams, Fox, Medicine Creek at Maywood, and Medicine Creek above Harry Strunk Lake, had 27, 17 and 23 per cent, respectively, of their eight year amounts occurring in 1951. A study indicates that most of the runoff volume from Dry, Mitchell, and Brushy Creeks is direct storm runoff. The flow duration curves show that flow occurs 5, 8, and 94 per cent of the time, respectively.

Because of the relatively short period and the climatological conditions existing during the study, the adequacy of the runoff data for representing a long period is questionable. In an effort to develop better runoff data for a long period, multiple regression methods, both linear and curvilinear, were used to compute prediction equations for runoff (Y cfs-days) in Dry Creek. Independent variables were rainfall amount (P inches), maximum hourly intensity for the storm (I inches per hour), and antecedent moisture (A inches). The best equation was

$$Y = 42.09^{*} P + 108.56^{**} I + 37.97^{**} A - 66.24$$

*t value statistically significant at the 5 per cent level
**t value statistically significant at the 1 per cent level

The coefficient of determination (R^2) for this equation was 0.554 and the standard error of estimate was 50.7 cfs-days. Because of the mediocre results, other methods for establishing an adequate record will be investigated.

Suspended Sediment

Most of the suspended sediment moving out of Medicine Creek watersheds during the period 1951-1958 was the result of a few large storms in 1951. In that year, annual rainfall was 10 inches above normal.

The annual suspended sediment loads which are given in table 1 vary by years for the six drainages.

The suspended sediment load in Dry Creek for 1951 was 73 per cent of the total during 1951-58. A one-day storm in 1951 of 2-3/4 inches produced 95,000 tons, or nearly one-fifth of the total sediment for the 8 years.

No data were collected on Mitchell Creek in 1951 and 1958. One storm occurring in 1957 accounted for one-eighth of the 1952-57 sum. About 91 per cent of the total suspended sediment leaving Fox Creek during the 8-year period occurred in 1951. Two storms in May and June of that year accounted for 225,000 tons, 39 per cent of the total. The largest annual sediment load for the other seven years was exceeded by six individual events in 1951.

In Brushy Creek the suspended sediment load in 1951 was 56 per cent of the total for the study period. Two storms produced more than one-fourth of the sediment for the eight years.

The sediment yield in 1951 at Medicine Creek above Maywood was about 60 per cent of the total. Two events in May and June of that year produced 18 per cent of the 1951-58 quantity.

Medicine Creek drainage above the Harry Strunk Lake gage includes the other tributaries listed in the table, except Mitchell Creek. The suspended sediment load for 1951 was 72 per cent of the period total. Four storms in 1951 produced 45 per cent of the 1951-58 amount.

1952-58 Dry Cr.

Sed Yield = 18,~~300~~ 36 tons/y

= 1.4 t/a/y

@ Curtis

1951 P = 31.61 inches

1952-58 $\bar{P}$ = 17.0 inches

1951-58 S.Y = 58,998 t/y

= 4.6 t/a/y

1951-58 $\bar{P}$ = 18.82 inches

Table 1

Tons of Suspended Sediment by Subwatersheds
per Water Year
(Determined from Runoff Samples)
Medicine Creek Watershed, Nebraska

Water Year	Dry Creek (20.45 sq.mi.)	Mitchell Creek (52.19 sq.mi.)	Fox Creek (72.63 sq.mi.)	Brushy Creek (73.74 sq.mi.)	Medicine Cr. above Maywood (74.17 sq.mi.)	Medicine Cr. above Harry Strunk (548.6 sq.mi.)
1951	343,633	--	526,594	300,633	141,386	3,047,334
1952	7,952	1,847	5,150	14,331	12,566	108,067
1953	6,990	1,406	868	4,191	4,363	74,984
1954	10,676	24,002	10,254	24,299	11,929	97,788
1955	2,099	51,539	7,242	3,266	8,230	78,980
1956	14,009	21,885	5,195	70,617	12,097	151,021
1957	78,728	89,479	19,136	103,223	24,210	533,675
1958	7,903	--	6,638	15,519	19,220	150,423
Total	471,991	191,158	581,077	536,079	234,001	4,242,272

Daily Suspended Sediment Discharge Relationships

The suspended sediment discharge relationships, as illustrated in figure 2-1 for Dry Creek, are being plotted for each gage. Curves were drawn through the plotted points and the following equations calculated:

Table 2

Prediction Equations for Daily Suspended Load

Creek	Prediction Equation	Coefficient of Determination (r^2)
Dry	$x = 14.1\ y^{1.45}$	0.90
Brushy	$x = 0.857\ y^{2.02}$	0.85
Mitchell	$x = 3.98\ y^{1.55}$	0.87

x = tons of suspended sediment per day
y = cfs-days of runoff per day

Statistical analyses of runoff-sediment load relationships for Dry Creek were also investigated by months and years. These were found to be very similar to the above equation. For Brushy and Mitchell Creeks, however, it is better to have more than one prediction equation because the rating curve relationships vary by months. A sediment rating curve should be plotted for each group of months and an effort made to develop prediction equations by such periods. This would have to be utilized with appropriate period flow duration curves.

Annual Runoff and Suspended Sediment Load Relationships

Total runoff and suspended sediment load per water year have an excellent relationship, as shown in figure 2-2 for Brushy Creek. This is also indicated by the high coefficients of determination for each of the equations in table 3. This relationship is not always simple curvilinear. When flows from perennial streams are plotted on logarithmic paper, a curve can result.

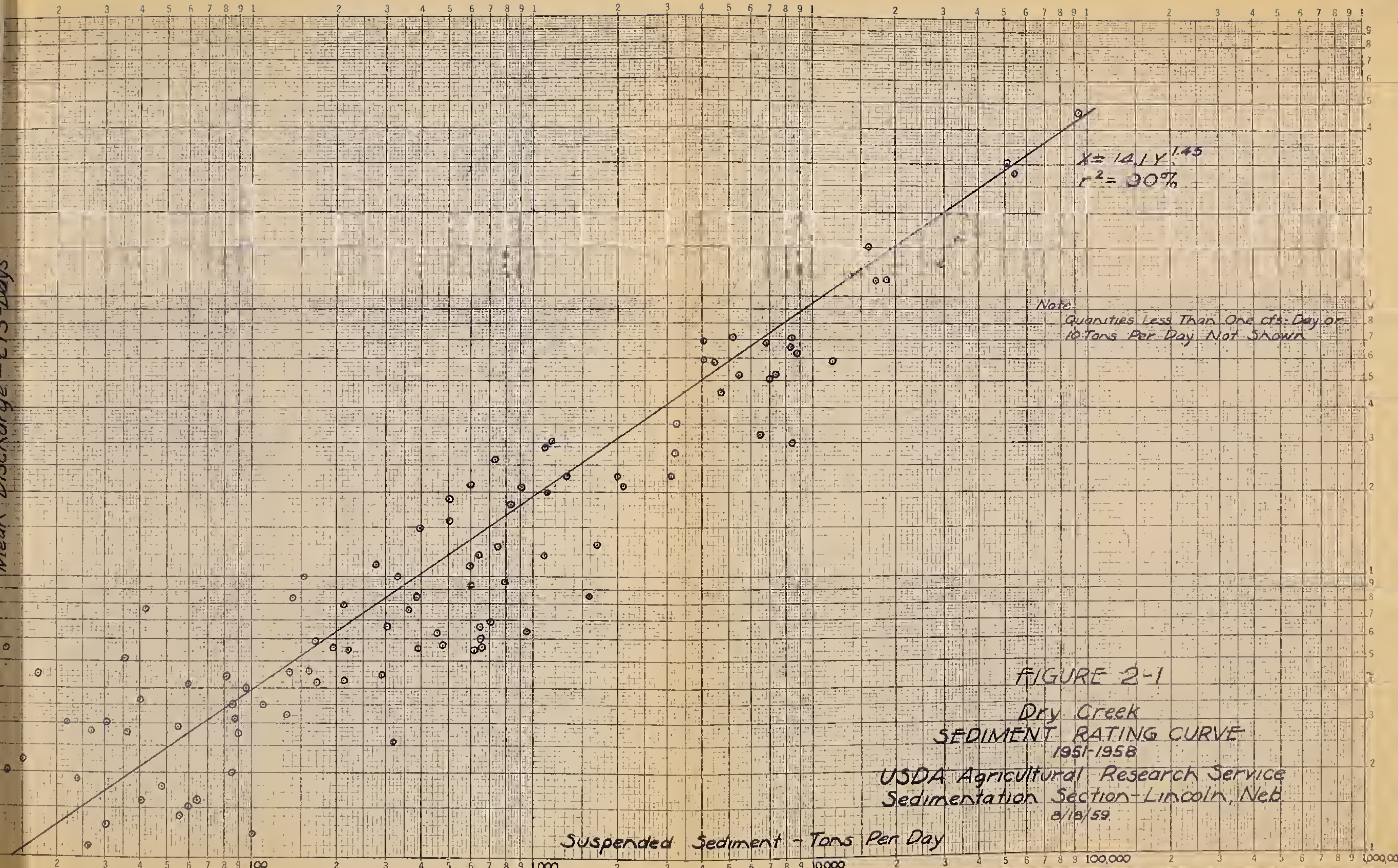


FIGURE 2-1

Dry Creek
SEDIMENT RATING CURVE
1951-1958

USDA Agricultural Research Service
Sedimentation Section - Lincoln, Neb
8/18/59

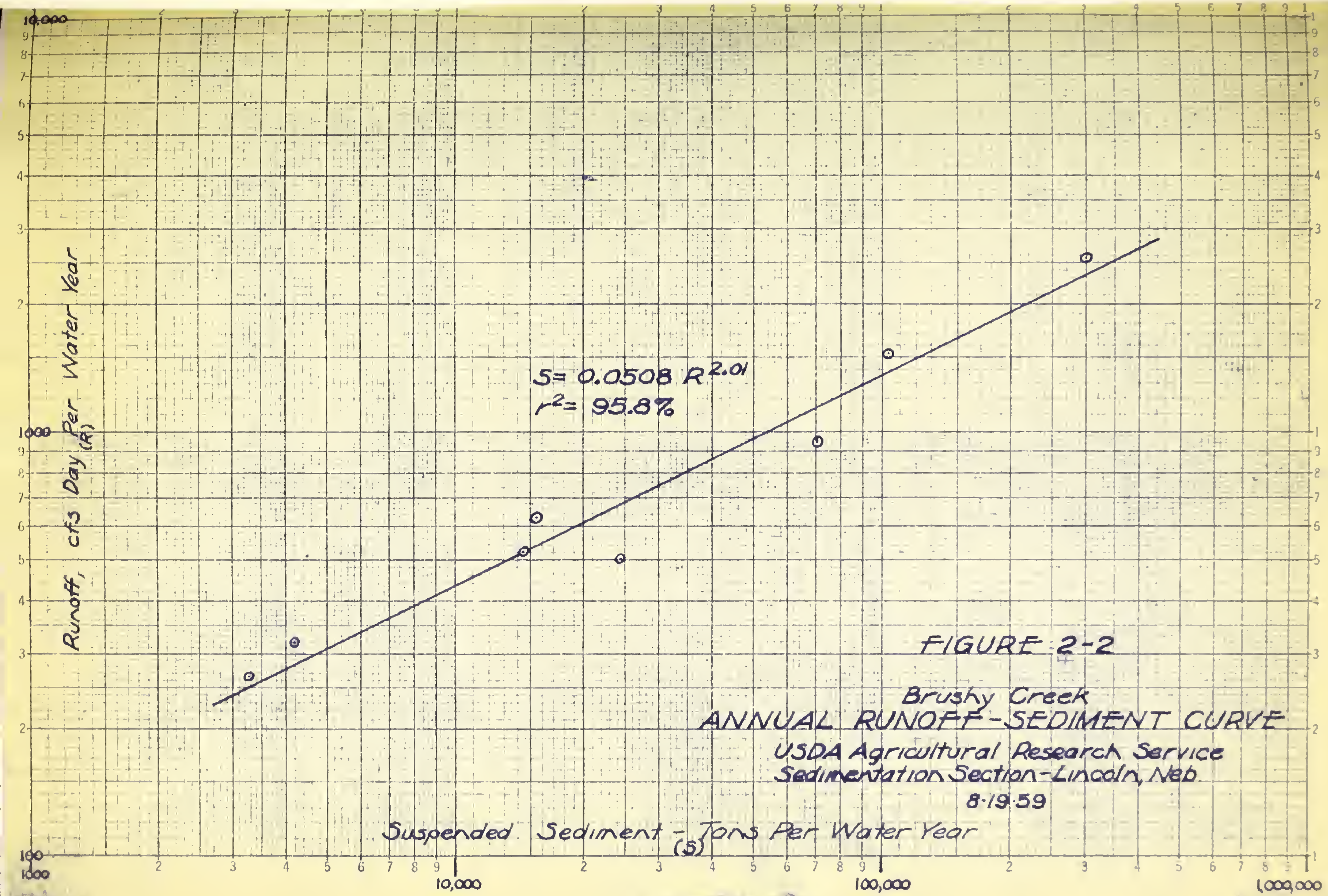


FIGURE 2-2

Brushy Creek
ANNUAL RUNOFF-SEDIMENT CURVE
USDA Agricultural Research Service
Sedimentation Section-Lincoln, Neb.
8-19-59

Table 3

Equations for Annual Runoff-
Suspended Sediment Load Relationships

Creek	Equation	Coefficient of Determination (r^2)
Dry	$S = 37.12\ R^{1.18}$	0.944
Mitchell	$S = 7.00\ R^{1.35}$	0.955
Brushy	$S = 0.0508\ R^{2.01}$	0.958

S = tons of suspended sediment per water year
R = cfs-days runoff per water year

Long Term Sediment Yield

The long term sediment yields for Dry, Brushy, and Mitchell Creeks were calculated, using three methods: (1) flow-duration, daily suspended sediment rating curve, (2) frequency of annual runoff with annual runoff-suspended sediment load relationships, and (3) daily suspended sediment sampling method. In the computations, no adjustments were made in flow-duration curves or in the frequency of annual runoff to compensate for the lack of representative precipitation.

Flow-Duration, Daily Sediment Load Method -- The flow-duration, daily sediment rating curve method of computing sediment yield is explained, with examples, in the publication entitled, "Analysis of Flow-Duration, Sediment-Rating Curve Method of Computing Sediment Yield," by Carl R. Miller.

Frequency of Annual Runoff with Annual Runoff-Suspended Sediment Load Curve -- The frequency of annual runoff with annual runoff-sediment load curve method requires the following computations to arrive at the sediment yield. The frequency of annual runoff can be determined by methods explained in Part 3.18 of the Soil Conservation Service Engineering Handbook, Section 4, Supplement A, "Hydrology."

The annual runoff-sediment load curve is illustrated in figure 2-2. A form combining frequency of runoff and the sediment load corresponding with that runoff is shown in table 4.

Table 4

Average Annual Sediment Yield by
Frequency of Annual Runoff with
Annual Runoff-Suspended Sediment Load Relationships

Brushy Creek

	Frequency of Annual Runoff	Runoff cfs days per year	Suspended Sediment tons per year	
	100	4150	970,000	
	50	3650	750,000	
	33.3	2900	470,000	
	25.0	2650	400,000	
x (1)	20.0	2440	340,000	
	16.7	2280	290,000	
	14.3	2150	260,000	
	12.5	2020	234,000	
	11.1	1930	210,000	
	10.0	1850	193,000	
			4,117,000	4,117,000
	6.72	1520	130,000	
	3.98	1150	73,000	
	2.84	930	46,000	
	2.20	760	31,500	
x (10)	1.81	620	20,500	
	1.53	510	13,750	
	1.33	425	9,500	
	1.17	325	5,450	
	1.038	183	1,675	
			331,375 (10) =	3,313,750
			Grand Total (tons in 100 years)	7,430,750
			Tons per year	74,308
			Ac-Ft. per mi^2 per yr.	0.60

Daily Suspended Sediment Sampling Method — Annual suspended sediment yields were also computed from the daily sediment sample concentrations recorded in USGS publications, "Quality of Surface Water of the United States." The results are shown in table 5.

These sample yields are less than those calculated by the flow-duration, daily sediment load method. The probable reason is that the flow duration curves are prepared by extending a portion of the high runoff to represent a 100-year series. It also can be seen from the sediment rating curves that an increase in runoff results in an increasing rate of sediment transported. The combination of these two conditions will increase the average annual yield by the flow-duration method.

The daily method also usually provides higher values than the annual method because in this system a more direct evaluation is made of the less frequent runoff events occurring in a long period. The large individual storms which produce the greater quantities of runoff and sediment do not lose their direct effects as when averaged in the annual computations.

It should be noted that the Mitchell Creek gage was in operation from 1952-57 missing the big runoff and sediment producing events of 1951.

Table 5

Average Suspended Sediment Yield in Acre-Feet per Square Mile per Year

	100 Year Period		
Creek	Flow-Duration, Daily Sediment Load Method	Frequency of Annual Runoff with Annual Runoff and Suspended Load Relationships	Suspended Sediment Sampling 1951-58
Dry	2.43	1.56	1.84
Brushy	1.21	0.60	0.58
Mitchell	0.50	0.61	0.36

EXPERIMENTAL OUTLINE NEB-LS-W-3, RESERVOIR FORMULAS

This is an office study to develop a uniform, accurate method of computing reservoir remaining capacities, sediment volumes and sediment weights. Because present methods of calculations are varied, it is difficult to compare results and to further analyze the information. It is important, therefore, that an accurate, uniform calculations procedure be devised and used by all workers in this field.

No specific work was directed toward this goal during the past year, but it was kept in mind during other studies. Additional experience gained by computations of the Newell, South Dakota Project reservoirs which were surveyed in considerable detail, emphasizes the desirability of having parallel ranges located quite close together. If this is done, a number of different formulas may be used, and all will give comparable results.

EXPERIMENTAL OUTLINE NEB-LS-W-4, SEDIMENT YIELD AS RELATED TO GULLY EROSION

Our primary purpose in this study is to develop criteria for estimating the significance of gullying as a sediment source. We wish also to study the importance of causal factors in this type of erosion as well as the effects of it. The investigations will be conducted at the following locations: Sabetha Watershed near Sabetha, Kansas; Dry Creek Watershed near Curtis, Nebraska; and in selected watersheds near Newell, South Dakota.

A series of cross-sections were accurately surveyed and range ends monumented in 14 separate gully and channel reaches in the Sabetha Watershed. This work was accomplished in 1957 by the SCS and ARS. Gullies and channels in the Dry Creek Basin were surveyed and monumented in 1951 and resurveyed about a year later. This was done by the Bureau of Reclamation. We also hope to establish permanent gully and channel cross-sections soon in watersheds near Newell, South Dakota.

No field work or any computations were performed during the past year in connection with this study. Previous work and results were covered quite thoroughly in the 1958 Annual Report.

EXPERIMENTAL OUTLINE NEB-LS-W-5, SEDIMENT DISTRIBUTION IN FLOODWATER RETARDING TYPE RESERVOIRS AND PONDS

The distribution of sediment that will accumulate in a proposed floodwater retarding reservoir has long been a problem in planning and design. If one knew how the sediment will be distributed, he could better determine the minimum elevation of the principal spillway, and the required capacities of the various storage pools.

The next 44 pages (8.1 - 8.44) is a report, "Sediment Distribution in Soil Conservation Service Floodwater Retarding Structures--Missouri Basin Loess Hills," which tells of our work on this item during the past year. This Report was presented in Mississippi last September. It should be emphasized that the material presented applies to small floodwater retarding structures in the Missouri Basin Loess Hills only. Additional analyses are planned or under way to study relationships applicable to other areas.

SEDIMENT DISTRIBUTION IN SOIL CONSERVATION SERVICE FLOODWATER RETARDING STRUCTURES-MISSOURI BASIN LOESS HILLS

Herman G. Heinemann

INTRODUCTION

The Soil and Water Conservation Research Needs reports prepared by the Soil Conservation Service have listed since 1955 a need for a determination of the distribution of sediment in floodwater retarding type structures. The July 1955 report listed it in Section B-I-B-4. This need has been given a higher priority since then and is now listed in the Soil Conservation Service report dated July 1, 1958, as Item I-B-4-a and b.

The Soil Conservation Service requests information on the distribution of reservoir sediment primarily to aid in the design of floodwater retarding type structures. Knowledge concerning sediment distribution will be of help in determining the total original reservoir capacity and the elevation of the crest of the drop inlet. This study is in response to these research needs.

The initial step in this study was a request to the Engineering and Watershed Planning Unit offices of the Soil Conservation Service for the results of their reservoir sedimentation surveys of floodwater retarding type structures. Varying amounts of data were received. Considerable information was obtained on reservoirs and ponds in western Iowa and on ponds and reservoirs in Oklahoma and Texas. Because of the proximity of the area, however, it was decided to work on the ponds in the loess hills of the Missouri Basin for the initial study. This area lies mainly in western Iowa and eastern Nebraska and is described in considerable detail on pages 5 and 6 of the T.P. #97 (6).1/

PROCEDURE

All of the available field notes concerning the ponds and reservoirs listed in the Soil Conservation Service T.P. # 97 were obtained from the Milwaukee office of the Engineering and Watershed Planning Unit. A field trip was also made to inspect each of these ponds and reservoirs and to obtain additional field data. Information was also received from other Soil Conservation Service offices and Iowa State College.

1/ Numbers in parenthesis refer to Literature Cited.

The first step in the use of these data was to review all the available information. This included checking the computations for determining the reservoir capacities by the range method (2). When minor errors were uncovered, they were not considered, and the information was left unaltered. However, when greater differences developed, an attempt was made to resolve them and use the correct capacities. If the differences could not be resolved, the pond and its data were eliminated from further study. The location of the remaining 23 ponds or reservoirs is shown in Figure 1.

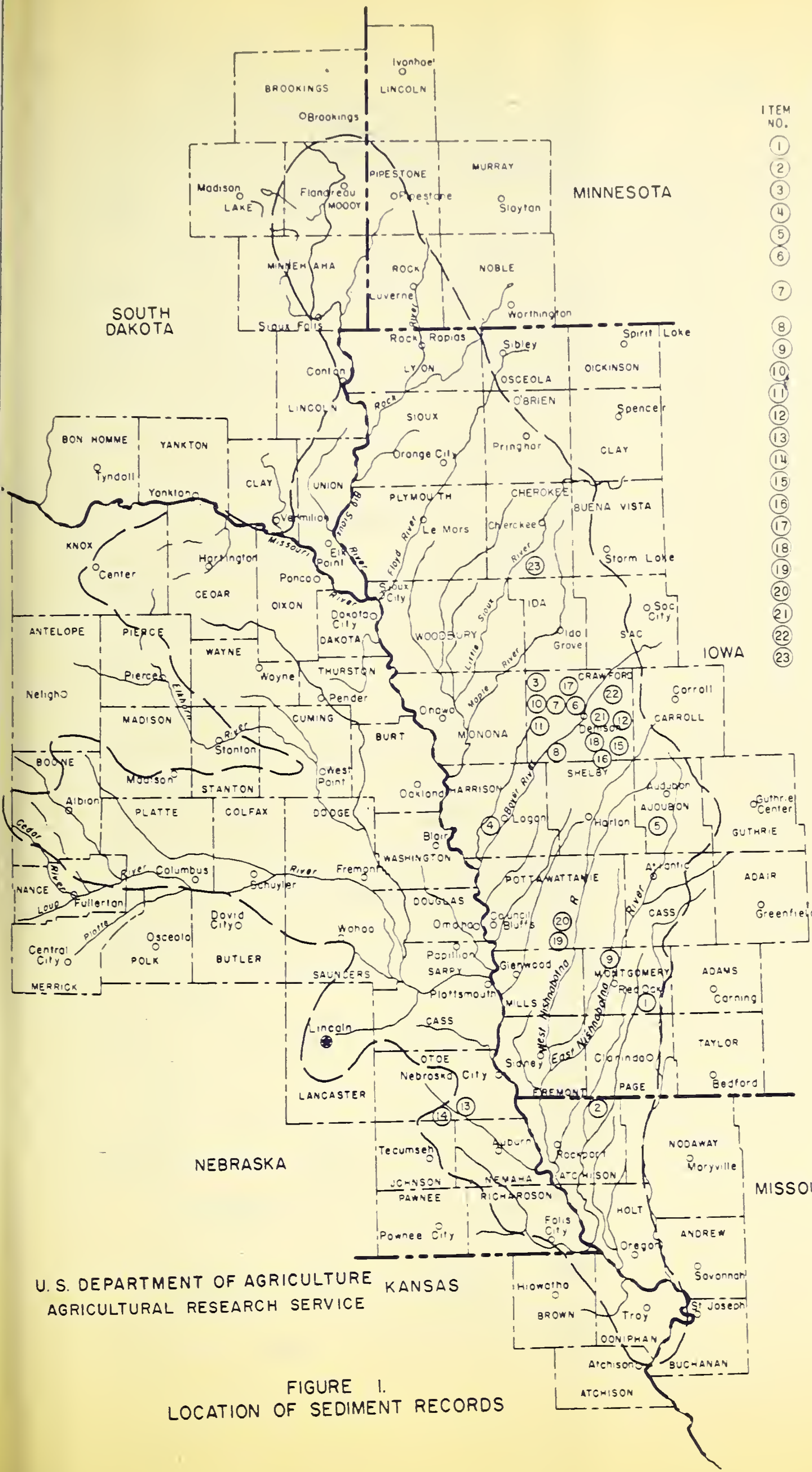
The plotting of the cross sections from the original survey notes was checked in every instance, and these cross sections were then used to develop a contour map for each survey of each pond or reservoir. Using data from these maps and the prismoidal formula, reservoir capacities were then calculated (5) for each survey. The accumulated capacities as derived from the contour method were adjusted to agree with the capacities as determined by the range method. This adjustment was made for the capacity below the drop inlet, as well as the capacity between the two spillways or above the drop inlet. The contour method capacities were adjusted to the range method capacities because the original surveys were made for the range method of computations and therefore presumed more accurate. A sample of the contour method of calculation and the adjustments is shown in Table 1.

This table shows the method used on the G. & A. Evers (lower) pond #35-4. For the most part this is self-explanatory, but it should be pointed out that the capacity values 6.63, 28.26, 1.26 and 20.96 were obtained from the range method computations. Adjustments to make the volumes agree were always made on the Volume Between Contours "V". The Accumulated Sediment Volume is the difference between the two Adjusted Accumulated Capacity columns. The last column shows the status of storage depletion, progressing from the original bottom of reservoir.

Sedimentation Information Curves

Data from the above tables which were prepared for each pond, were then plotted and curves drawn. Depths, capacities, sediment volumes and storage depletion information were plotted in percentages so that the curves on one pond can be compared with those of another. A set of the following three types of curves was prepared on a single sheet of graph paper for each of the ponds.

A. Original Stage-Capacity showing the capacities at the date of construction.



LEGEND

ITEM NO.	DATA SUMMARY SHEET NO.	
1	31-2	Carl Chinquist
2	31-3	L. H. Fuelling
3	35-1	Otto Baak
4	35-2	Fred Brown
5	35-3	Wm. Esbeck
6	35-4	G. and A. Evers, (Lower Reservoir)
7	35-5	G. and A. Evers, (Upper Reservoir)
8	35-6	Chas. Fienhold
9	35-7	C. T. Gadd
10	35-8	Otto Goslar
11	35-10	Fred Hollrah
12	35-12	Emma La Frontz
13	35-13	Jensen - O'Neil
14	35-14	Clarence Petersen
15	35-15	Alfred Lage
16	35-16	Herman Lage
17	35-17	Howard Mattson
18	35-18	Wilbur Meyer
19	35-19	Max Miller No. 1
20	35-20	Max Miller No. 5
21	35-21	Barney Mundt
22	35-22	Tracy North
23	36-2	C. A. Stiles

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AGRICULTURAL RESEARCH SERVICE

FIGURE 1.
LOCATION OF SEDIMENT RECORDS

RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION

FILE 8.4

COMPUTATIONS OF: G.&A. EVERS, Lower 35-4 ~ Remaining Capacities ~ TABLE 1
Sediment Distribution Project ~ Missouri Basin Loess Hills ~ Sedimentation Section - Lincoln, Neb.

		ORIGINAL SURVEY 12/1938							1st SURVEY 4/1949							
Elev. ft.	Diff. in Elev. (L)	% of Total Depth	Contour Area "A" (Acres)	Contour Area "B" (Acres)	Volume Between Contours (AF) (V)	Accum. Capacity (A.F.)	Adj. Accum. Cap. (AF)	Cap. in %	Contour Area "A" (Acres)	Contour Area "B" (Acres)	Volume Between Contours (A.F.) (V)	Accum. Capacity (A.F.)	Adj. Accum. Cap. (AF)	Accum. Sediment Volume (AF)	% Total Sediment 1949	% Accum. Orig. Cap. Occupied by Sed.
91.8		0.00	0													
	0.2				0.007											
92		1.33	0.106	0.106		0.007	0.01	0.04						0.01	0.01	100.00
	2.0				0.516											
94		14.67	0.450	0.450		0.523	0.51	1.80						0.51	6.99	100.00
	2.0				1.209											
96		28.00	0.774	0.774		1.732	1.68	5.94						1.68	23.01	100.00
	2.0				2.051											
98		41.34	1.299	1.299		3.783	3.66	12.95						3.66	50.14	100.00
	2.0				3.074											
98.4									0			0				
	0.6										0.089					
99									0.445	0.445		0.089	0.14			
	1.0										0.718					
100		54.67	1.788	1.788		6.857	6.63	23.46	1.031	1.031		0.807	1.26	5.37	73.56	81.00
	2.0				4.480						3.321					
102		68.00	2.725	2.725		11.337	11.11	39.31	2.383	2.383		4.128	4.51	6.60	90.41	59.41
	2.0				6.119						5.768					
104		81.34	3.407	3.407		17.456	17.23	60.97	3.416	3.416		9.896	10.16	7.07	96.85	41.03
	2.0				7.549						7.559					
106		94.67	4.155	4.155		25.005	24.78	87.69	4.155	4.155		17.455	17.56	7.22	98.90	29.14
	0.8				3.474						3.474					
106.8		100.00		4.532		28.479	28.26	100.00		4.532		20.929	20.96	7.30	100.00	25.83

Adjustment Factors:

$$\frac{6.63}{6.857} = 0.96689 \qquad \frac{1.26}{0.807} = 1.56133$$

$$\frac{28.26 - 6.63}{28.479 - 6.857} = \frac{21.63}{21.622} = 1.00036 \qquad \frac{20.96 - 1.26}{20.929 - 0.807} = \frac{19.70}{20.122} = 0.97902$$

Formula Used: $V = \frac{L}{3}(A + \sqrt{AB} + B)$

B. Sediment Distribution developed from the changes in capacities between the time of construction and sedimentation surveys.

C. Storage depletion shown as Capacity Replaced by Sediment.

A set of these curves provides a great deal of information on the sediment history and distribution in the reservoir. Pond 35-4 is again used as a sample (See Figure 2).

Since the total original capacity and depth are shown, the original capacity can be computed to any elevation. The Original Stage Capacity curve shows, as an example, that about 20% or 5.65 A.F. of capacity were originally located in the bottom 50% or 7.5 ft. of the reservoir. Of course, the more horizontal a segment of this curve is, the more capacity there is available within the given segment of depth.

The Sediment Distribution curve shows where sediment trapped in the reservoir was located as of the date of the sedimentation survey - April, 1949. This shows, as an example, that about 73% of the sediment in the reservoir is located below the crest elevation of the drop inlet. The flatter segments indicate the elevations between which the highest percentages of the sediment have been deposited. Only 10% of the sediment is located in the upper 32.5% of the reservoir.

The Capacity Replaced by Sediment curve shows, in effect, the storage depletion up to a given elevation. In this pond, 100% of the storage in the bottom 41% of the reservoir depth was depleted by sediment as of the survey date. This means that the bottom of the reservoir is now 41% x 15 ft. or over 6 ft. higher than it was originally. The total capacity lost to the elevation of maximum capacity is about 26%.

If the Original Stage Capacity and Capacity Replaced by Sediment curves are available, the Sediment Distribution can be computed. If the Original Stage Capacity and Sediment Distribution curves are available plus the total sediment volume, the Capacity Replaced By Sediment can be computed. If more than one sedimentation survey was made on a pond, additional Sediment Distribution and Capacity Replaced by Sediment curves were plotted for the additional surveys. The 23 sets of curves for the ponds studied are included in the Appendix as Figure 6 to Figure 28.

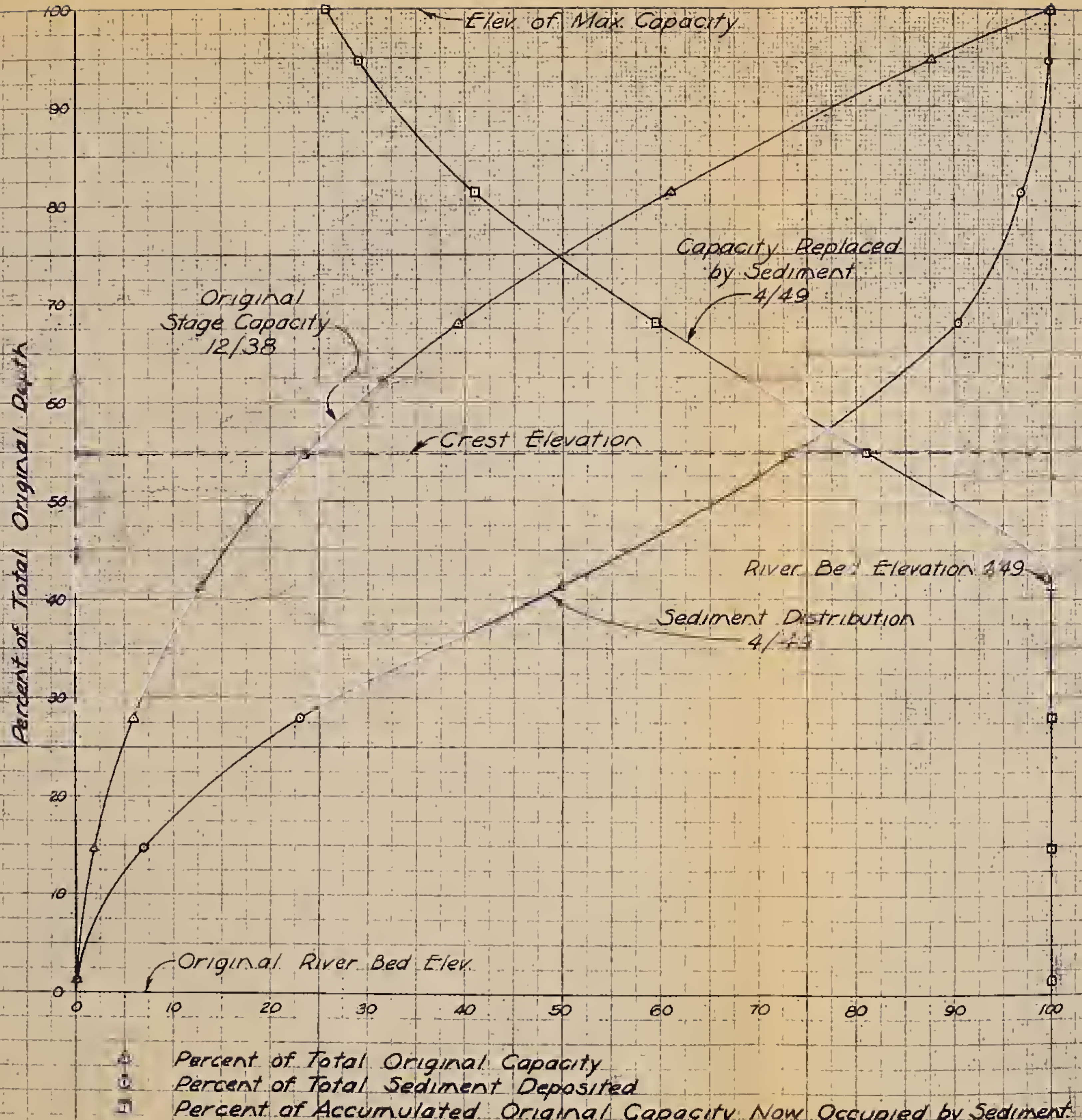

FIGURE 2

G. & A. EVERS, LOWER (IOWA) 35-4

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/4/59

Data Tables

An effort was made to obtain a quantitative value or measure of every sedimentation, reservoir, and watershed parameter believed to have an effect on sediment distribution. This attempt was not completely successful, however, considerable information was collected or computed. This is recorded in Table 6 in the Appendix. Most of the column headings are self-explanatory, but some need further elaboration.

Reservoir Capacity and Sediment Information

The Data Summary Sheet referred to in column 1 is the Reservoir Sedimentation Data sheets compiled by the member agencies of the Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources (4). Column 9 includes the storage capacity up to the elevation of maximum capacity. In this report, this is the elevation of the emergency spillway or of the critical storage elevation when there is no emergency spillway. Column 12 of this same table is the percentage of the total available storage capacity that is located above the drop inlet or between spillways. Column 16 is not adjusted for trap efficiency, nor is the sediment located above the elevation of maximum capacity included at any time.

Reservoir Data

Column 18 is the surface area at the elevation of maximum capacity. The Length of Reservoir, column 19, was determined by measurement on the contour map of the distance from the dam up the valley to the most distant point at the elevation of maximum capacity.

Column 20, "n" Values, is the slope of the plottings on log-log paper of the original depth versus capacity. It is a topography factor. This parameter was originally used by Sutherland (11) to type reservoirs as to shape. The Bureau of Reclamation has also used this factor in their work on distribution of sediment (1, 9, 12). They classify reservoirs as follows:

"n" Value	Reservoir Type	Standard Classification
0.22 to 0.28	Lake	I
0.28 to 0.40	Flood plain-foothill	II
0.40 to 0.67	Hill	III
0.67 to 1.00	Gorge	IV

Column 21, Reservoir Shape Factor, is the circularity factor developed by Miller (8). He defines it as the ratio of basin area to the area of a circle having the same perimeter (7). He states that "A circle provides maximum area with minimum perimeter whereas a long, narrow drainage basin will have a large perimeter, but a small area. An index of drainage basin circularity affords a quantitative basis of comparison of the form of basins . . . ." In this column the factor designates the circularity of the water surface in the reservoir at the elevation of maximum capacity.

Column 22 does not include the reservoir area. It is the net sediment contributing area. The Capacity-Watershed Ratio, column 23, is for the entire storage, not that between spillways, or above the drop inlet alone. The area described in column 22 was used in this ratio. Column 24 is the lowest reservoir elevation given in the reservoir sedimentation survey field notes. Detention Time, column 28, may not be a very reliable figure as several different methods were used in deriving the values. It is the estimated length of time required to pass the runoff from a 50 yr. design storm through the drop inlet.

Watershed Data

Basin Length, column 29, is the measured distance, on a drainage area map, from the dam up the valley to the most distant point. Column 30 is the circularity factor explained for column 21, except that in this column the factor designates the circularity of the entire drainage area. The area of the reservoir was included in the area of the watershed. Time of Concentration, column 31, is the estimated time required for runoff to reach the reservoir area from the most distant point in the watershed or from another point, but requiring a longer time. Because of changes between surveys in slopes, additions of terraces and diversions, this factor may be subject to some question.

It is believed necessary to include parameters of rainfall or runoff to arrive at some indication of water stage in the ponds. Runoff, however, was deleted from further consideration after inspection of available records on small watersheds in this area. Adequate precipitation records are available for this area so these were scrutinized. For this study it was assumed that runoff does not take place until there has been at least a half inch of rainfall during the rainfall event. Column 32 is the total number of these events between the date of construction and the date of the last sedimentation survey. Column 33 is the total amount of precipitation occurring during those events which exceeded 0.5 inch, during the period of study of the pond.

Analyses Of Data

Two approaches were used in the analyses of the data. These are the graphical and statistical methods.

The graphical approach was used principally to determine the relationship between various parameters and also as an aid in determining their importance as independent variables. Approximately 35 such relationships were investigated. A few of these will be discussed later in this report.

Multiple regression methods (3, 10) were used to evaluate parameters that appeared to have an influence on the dependent variable. Table 2 gives the values of the variables used in the multiple regression.2/

Since one of the primary reasons for needing information on sediment distribution is to aid in establishing the crest elevation of the drop inlet, the dependent variable must provide a means of obtaining that elevation. In this study, it is expressed as the percent of the original depth that is completely filled with sediment. The dependent variable "Y", Percent Original Reservoir Depth Filled With Sediment, was obtained from the Capacity Replaced By Sediment curves Figures 6 to 28. This figure was read off of the Percent Of Total Original Depth ordinate at the highest point where storage depletion was 100%.

The independent variable D, Total Original Storage Depletion, is column 17 of Table 6. It is the percent of the original reservoir capacity that has been filled with sediment. Variable N, "n" Value, is the same as column 20 of Table 6 and has been explained. Variable S, Total Storage Capacity, is the same as column 9 and a comment has also been made previously to elaborate on its meaning. Variable W, Sediment Sample Volume Weight, is column 8 and should need no further explanation. Variable C, C/W Ratio, is column 23 of Table 6 and is expressed in Acre Feet per Square Mile. This parameter is the storage capacity divided by the contributing drainage area.

RESULTS

Regression Analyses

Regression analyses were run on 12 combinations of the five independent variables to determine the best combination for computing the dependent variable. Table 3 summarizes these regression equations and indicates the ability of each.

2/ The assistance of Verne I. Dvorak in setting up and directing the multiple regression analyses is gratefully acknowledged.

Table 2

VARIABLES CONSIDERED IN REGRESSION ANALYSES

Summary Sheet No.	Name	Date	% Orig. Res. Depth Filled with Sediment	Total Orig. Storage Depletion %	Orig. "n" Value	Remaining Storage Capacity A.F.	Sed. Sample Volume Wt. Lb/ft^3	Orig. C/W Ratio AF/mi^2
			Y	D	N	S	W	C
31-2	Chinquist	5/49	55.3	48.27	0.47	8.52	50.0	92.50
31-3	Fuelling	5/49	59.3	51.14	0.37	33.50	62.9	65.93
35-1	Baak	4/49	36.5	25.12	0.38	16.81	54.8	142.99
35-2	Brown	5/49	51.6	34.06	0.49	15.12	63.8	236.39
35-3	Esbeck	5/49	51.3	43.68	0.49	11.19	56.1	97.40
35-4	Evers, Lower	4/49	41.8	25.83	0.41	20.96	68.4	217.38
35-5	Evers, Upper	4/49	71.6	63.50	0.46	1.19	71.6	74.10
35-6	Fienhold	4/49	52.2	36.08	0.47	17.45	63.1	64.24
35-7	Gadd	5/49	20.8	11.46	0.49	12.82	63.0	183.30
35-7	Gadd	6/52	32.3	17.27	0.49	11.98	57.3	162.30
35-8	Goslar	3/49	30.5	13.81	0.41	11.80	69.1	95.07
35-10	Hollrah	3/49	27.6	17.03	0.42	31.14	57.6	172.90
35-12	LaFrontz	4/49	37.7	32.07	0.44	10.38	56.4	100.50
35-12	LaFrontz	7/53	51.5	38.02	0.44	9.47	62.0	68.30
35-13	Jensen-O'Neil	11/48	23.8	24.28	0.40	31.18	54.7	213.37
35-14	Peterson	11/48	56.9	55.04	0.47	1.74	61.0	52.30
35-15	A. Lage	4/49	32.8	23.77	0.42	8.56	54.0	58.80
35-15	A. Lage	6/52	46.3	36.42	0.42	7.14	53.3	44.81
35-16	H. Lage	4/49	4.0	10.44	0.62	10.81	55.1	335.28
35-16	H. Lage	6/52	13.2	25.77	0.62	8.96	49.3	300.28
35-17	Mattson	4/49	33.9	23.60	0.48	12.56	69.0	167.75
35-17	Mattson	7/53	62.0	45.80	0.48	8.91	87.1	128.16
35-18	Meyer	4/49	21.8	14.77	0.37	37.33	58.0	149.49
35-18	Meyer	6/52	39.4	20.94	0.37	34.63	63.6	127.41
35-19	Miller No. 1	5/49	30.6	26.79	0.51	35.75	64.9	223.99
35-19	Miller No. 1	6/52	41.8	34.26	0.51	32.10	69.5	163.99
35-20	Miller No. 5	5/49	40.2	21.15	0.42	41.94	69.2	233.99
35-20	Miller No. 5	6/52	41.0	22.81	0.42	41.06	73.1	183.95
35-21	Mundt	4/49	40.0	28.04	0.36	33.08	54.0	139.30
35-21	Mundt	6/52	50.8	36.44	0.36	29.22	53.3	100.24
35-22	North	3/49	25.4	17.68	0.41	40.04	52.4	204.37
35-22	North	7/53	36.4	23.09	0.41	37.41	56.5	168.24
36-2	Stiles	9/50	7.0	11.41	0.43	69.10	47.3	136.34
36-2	Stiles	2/53	10.2	13.20	0.43	67.70	57.8	120.79

Table 3

EFFICIENCY OF REGRESSION EQUATIONS

Equation Number	Dependent Variable	Independent Variable	Multiple Correlation Coefficient R	Coefficient of Determination R^2	Degrees of Freedom	Standard Error	Confidence Limits ±50 Percent	±95 Percent
						Percent	Percent	Percent
1	Y	D	0.883	0.78	32	7.66	5.23	15.60
2	Y	D N	0.909	0.83	31	6.73	4.60	13.73
3	Y	D N S	0.919	0.84	30	6.34	4.33	12.95
4	Y	D N W	0.942	0.89	30	5.39	3.68	11.01
5	Y	D N C	0.906	0.82	30	6.83	4.66	13.94
6	Y	D S W	0.907	0.82	30	6.77	4.62	13.82
7	Y	D N S W	0.953	0.91	29	4.88	3.33	9.98
8	Y	D N S C	0.918	0.84	29	6.37	4.35	13.03
9	Y	D N W C	0.940	0.88	29	5.47	3.74	11.19
10	Y	D S W C	0.919	0.84	29	6.35	4.34	12.99
11	Y	N S W C	0.758	0.58	29	10.50	7.17	21.50
12	Y	D N S W C	0.952	0.91	28	4.95	3.38	10.14

Legend

Y = % Original Reservoir Depth Filled with Sediment
D = Total Original Storage Depletion, %
N = Original "n" Value

S = Total Storage Capacity, A.F.
W = Sed. Sample Volume Weight, Lb/ft^3
C = Capacity Watershed Ratio, AF/mi^2

Equation 1 in Table 3 has but one independent variable, D, Total Original Storage Depletion, in percent. The correlation coefficient, R, is 0.883 and the Coefficient of Determination, R^2, is 0.78. This is a high coefficient and it means that storage depletion is a very important factor in predicting Y. In fact, 78% of the variations in Y are caused by variations in D. The Degrees of Freedom for this equation are 32. This means that D in this case had 32 chances of being used independently in the determination of the dependent variable Y. It also means that two of the statistics calculations have been made and that 32 numbers remain for further use. The next column shows that the Standard Error of this regression equation is 7.66%. This is the closeness with which new estimated values may be expected to approximate the true values. The next two columns show the confidence that one can place in the equation. In other words, equation 1 will provide a way of computing the dependent variable that will probably be within 5.23% of the actual value in 50% of the cases. Also, in 95% of the cases the computed value will be within 15.6% of the actual percent depth.

The other equations in Table 3 have additional independent variables or combinations of them. These equations constitute an attempt to secure the best equation for determining the dependent variable Y. The ability of each is shown, indicating also little difference between 7 and 12. Equation 7 is the most efficient equation, however, having $R^2 = 0.91$, one more degree of freedom and slightly better confidence limits than equation 12.

The 12 complete equations are shown in Table 4. All of them are valid and can be used to compute the dependent variable. However, they have less desirable confidence limits than equation 7, as shown in Table 3.

Statistical data on the most efficient regression, equation 7, are presented in Table 5. The equation itself is reproduced in the vertical in the first two columns. All four of the independent variables in this equation are significant at about the one percent level or less. This is determined from the ratio of b divided by Sb and a probability table on the distribution of t(10). Being significant at the one percent level means that if the experiment is repeated it would be expected in 99 out of 100 cases that the importance of each variable would again be established.

Variable D, Total Original Storage Depletion, has the highest Simple correlation with the dependent variable Y. Variables S and W are next and about equal in importance. The Simple correlation is a correlation between the dependent variable and the individual independent variable, with the influence of the other variables still present. In the Partial correlation,

Table 4

REGRESSION EQUATIONS

Equation Number	Equation
1	$Y = 7.12 + 1.06\ D$
2	$Y = 34.1 + 1.07\ D - 60.8\ N$
3	$Y = 50.0 + 0.957\ D - 79.8\ N - 0.183\ S$
4	$Y = 7.03 + 0.982\ D - 63.1\ N + 0.500\ W$
5	$Y = 34.2 + 1.09\ D - 65.4\ N + 0.008\ C$
6	$Y = -18.9 + 0.974\ D - 0.0263\ S + 0.483\ W$
7	$Y = 22.6 + 0.886\ D - 81.2\ N - 0.175\ S + 0.494\ W$
8	$Y = 51.9 + 1.00\ D - 92.7\ N - 0.199\ S + 0.020\ C$
9	$Y = 6.61 + 0.980\ D - 60.8\ N + 0.506\ W - 0.00403\ C$
10	$Y = -11.1 + 0.841\ D - 0.042\ S + 0.526\ W - 0.042\ C$
11	$Y = 37.7 - 54.8\ N - 0.392\ S + 0.763\ W - 0.086\ C$
12	$Y = 23.6 + 0.903\ D - 85.8\ N + 0.181\ S + 0.487\ W + 0.00711\ C$

Table 5

STATISTICAL DATA ON MOST EFFICIENT REGRESSION, EQUATION 7

Partial Regression Coefficient b	Variable			Standard Error, Sb of Partial Regression Coefficient	Ratio b/Sb	Correlation with Dependent Variable Y		Beta Co-efficient
	Symbol	Name	Units			Simple	Partial	
	Y equals	Orig. Res. Depth Filled with Sediment	Percent					
0.886	D	Total Original Storage Depletion	Percent	0.0628	14.112	0.88	0.90	0.74
-81.2	N	Original "n" Value	--	15.133	5.368	-0.22	-0.69	-0.30
- 0.175	S	Total Storage Capacity	Acre-Feet	0.0638	2.749	-0.46	-0.43	-0.18
0.494	W	Sediment Sample Volume Weight	Lb/Cu.Ft.	0.1059	4.664	0.45	0.64	0.25
	+22.6	(Constant)						

the influence of each independent variable on the dependent is isolated by holding constant the effects of the other variables. This, therefore, is a measure of the relationship without the interaction of other variables. In this column, D again is most important, followed by N, W, and S in that order. The mathematical signs before the values in the Simple and Partial correlation columns indicates the slope of the curve showing how the dependent variable changes with increases in the independent variable. The beta coefficient is another measure of the value of each of the variables. It is a measure of the effect that one standard error in the independent variable will have on the dependent variable.

Using the most efficient equation, 7, and actual field data, the dependent variable, Original Reservoir Depth Filled With Sediment, was computed. This was compared with the actual Y and the points plotted in Figure 3. Departures of the points from the solid line are caused by other independent variables not included in the final equation.

Graphical

In addition to the above regression analyses, several other relationships were found that are of value in this study. Figure 4, Remaining Storage - Depth Ratio Curve, shows the relationship between the percent of the total remaining storage that exists between spillways (col. 12 of Table 6) and a depth ratio of (drop inlet crest elevation -- river bed elevation) divided by (elevation of maximum capacity -- river bed elevation). Of course, this curve is not applicable when all of the remaining storage is located above the crest elevation of the drop inlet. The coefficient of determination, r^2, for this curve is 0.95. The equation is, Y = square root of (11,140 - 11,860X). An attempt was made to improve the determination for Y, Percent of Total Remaining Storage Existing Between Spillways, by adding other independent variables and making a multiple regression analysis. This attempt was not successful.

As mentioned previously in the discussion of the Sedimentation Information Curves, if the Original Stage Capacity and Capacity Replaced By Sediment curves are available, the Sediment Distribution can be computed. In order to obtain a point for assistance in plotting the curved portion of the Capacity Replaced By Sediment curve an effort was made to determine the mid-ordinate of this curve. The length of a straight line between the river bed elevation and the point at the elevation of maximum capacity, was measured on the Capacity Replaced By Sediment curve, Figure 6 to Figure 28. The scale used for this measurement was the same as the scales used in these figures. The straight line was drawn

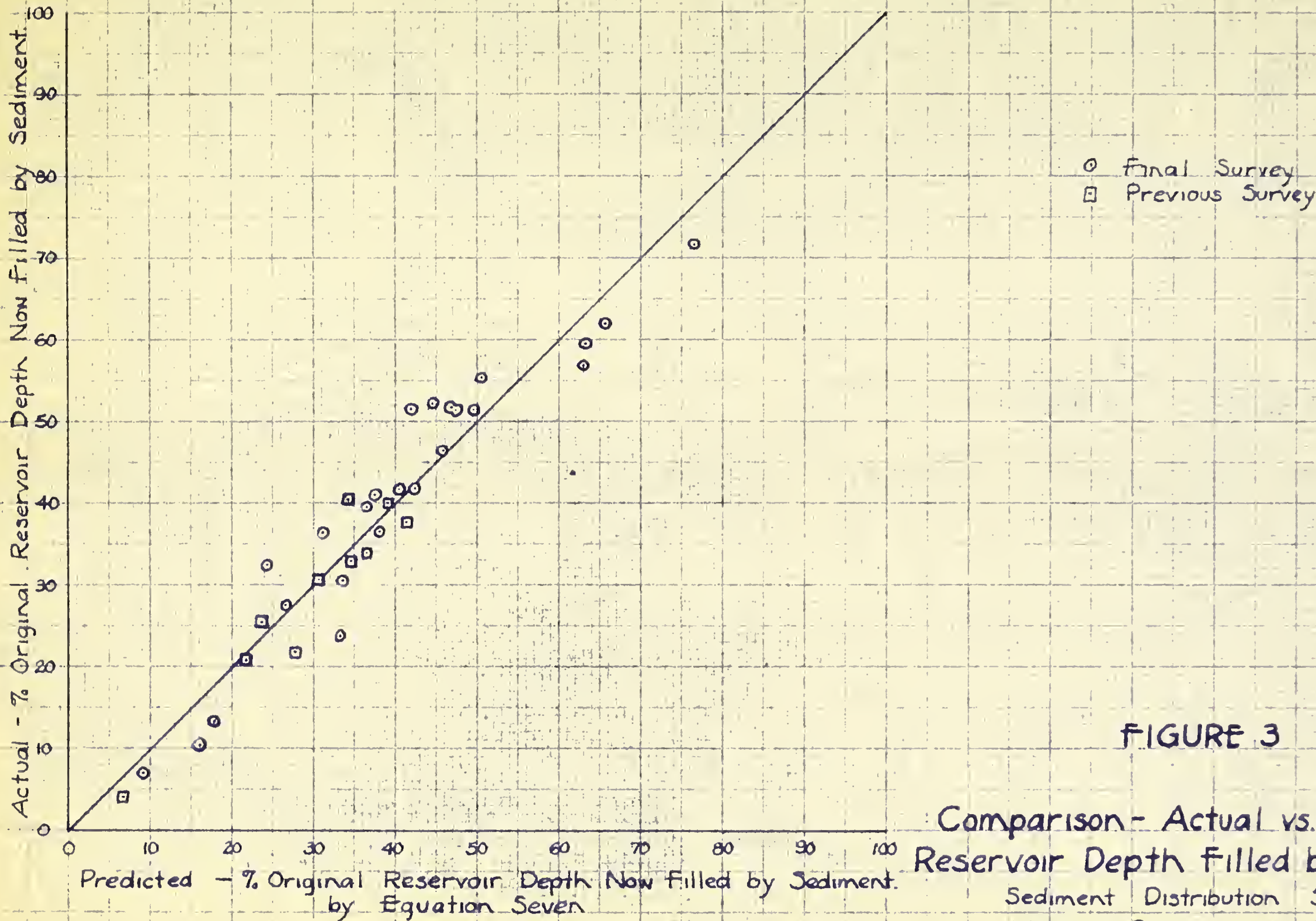

FIGURE 3

Comparison - Actual vs. Predicted
Reservoir Depth Filled by Sediment
Sediment Distribution Study
Missouri Basin Loess Hills
Sedimentation Section - Lincoln, Nebr.
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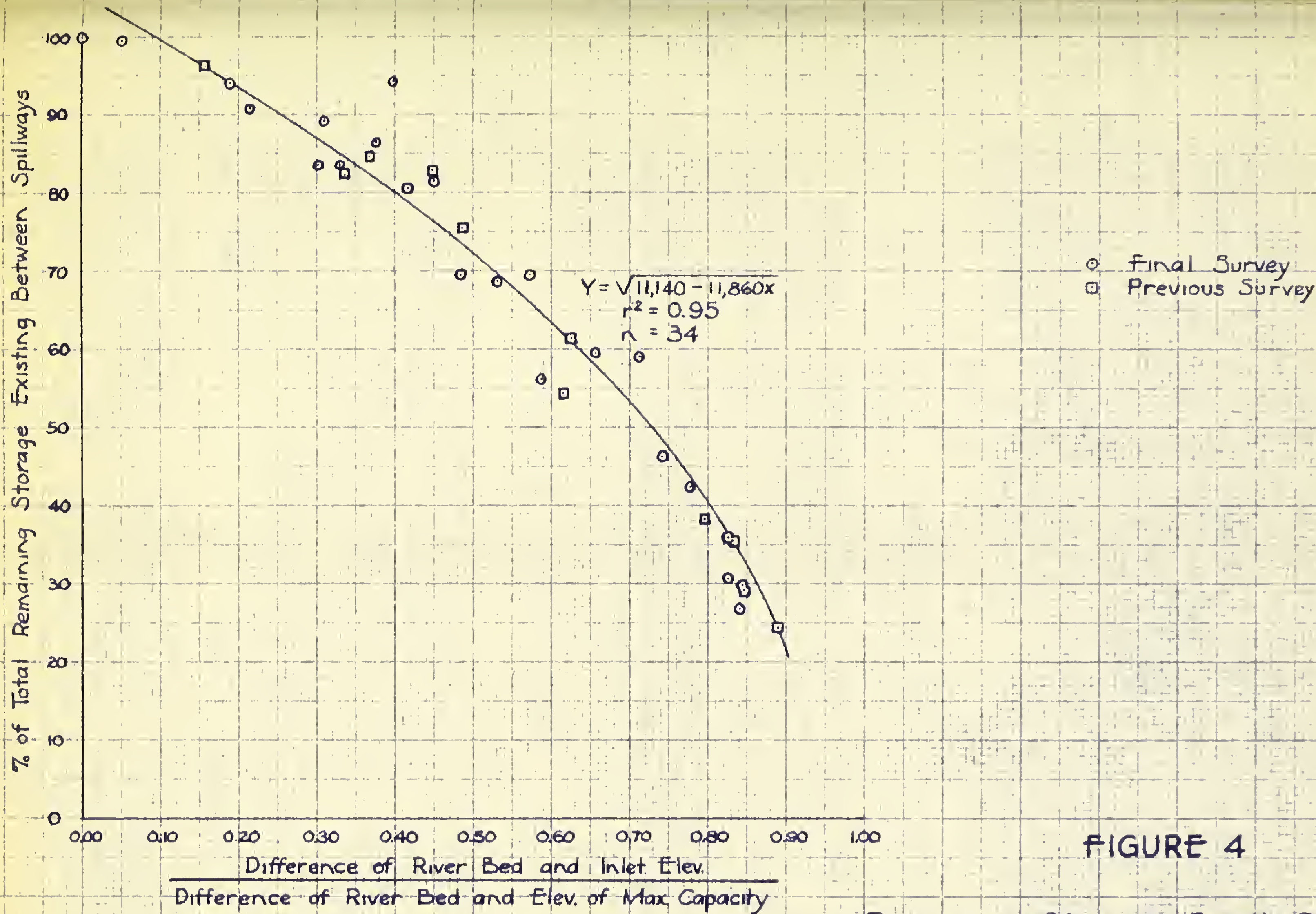

FIGURE 4

Remaining Storage-Depth Ratio Curve

Sediment Distribution Study

Missouri Basin Loess Hills

Sedimentation Section – Lincoln, Neb.

7·30·59 CSH

in and a perpendicular line constructed at the mid-point. This perpendicular line was extended until it intersected the curved portion of the Capacity Replaced By Sediment curve. This perpendicular line (mid-ordinate) was measured and assigned a positive sign if the mid-ordinate extended to the left and below the straight line, and a negative sign if the mid-ordinate extended to the right and above the straight line. A curve showing the relationship between the length of the straight line and the length of the mid-ordinate is shown in Figure 5. The equation of this curve is $Y = 0.002849X^{1.894} - 10$, and the coefficient of determination $r^2 = 0.77$. Attempts were made to improve the determination of the mid-ordinate by adding other independent variables and making a multiple regression analysis. These attempts did not improve on the graphic solution shown in Figure 5.

DISCUSSION

This is a study of the sediment distribution in some floodwater retarding structures in the Missouri Basin loess hills. One of the primary reasons for wanting knowledge on this subject is to help in determining the crest elevation of the drop inlet.

The data on the 23 ponds and reservoirs used in this study are believed to be generally good. The results having been determined by accepted procedures should then be very reliable within the stated limits for each solution.

Sediment Information Curves

The sedimentation information curves Figure 6 to Figure 28 are an excellent way to show the sediment history and distribution for a pond or reservoir. In these curves original capacity, sediment distribution and storage depletion are related to the original total depth with all values being converted to percent of total. With units in percent, the curves for one pond can be compared readily with those for another pond. It was hoped that a comparison of the shapes of these curves would provide a basis for separating the ponds into different groups, but no such basis was found.

Considerable knowledge can be obtained from a study of these curves. A comparison of them reveals that the Stage-Capacity curves for all ponds are almost identical. There is very little difference between them. This is undoubtedly due to the fact that all ponds are located in one general problem area.

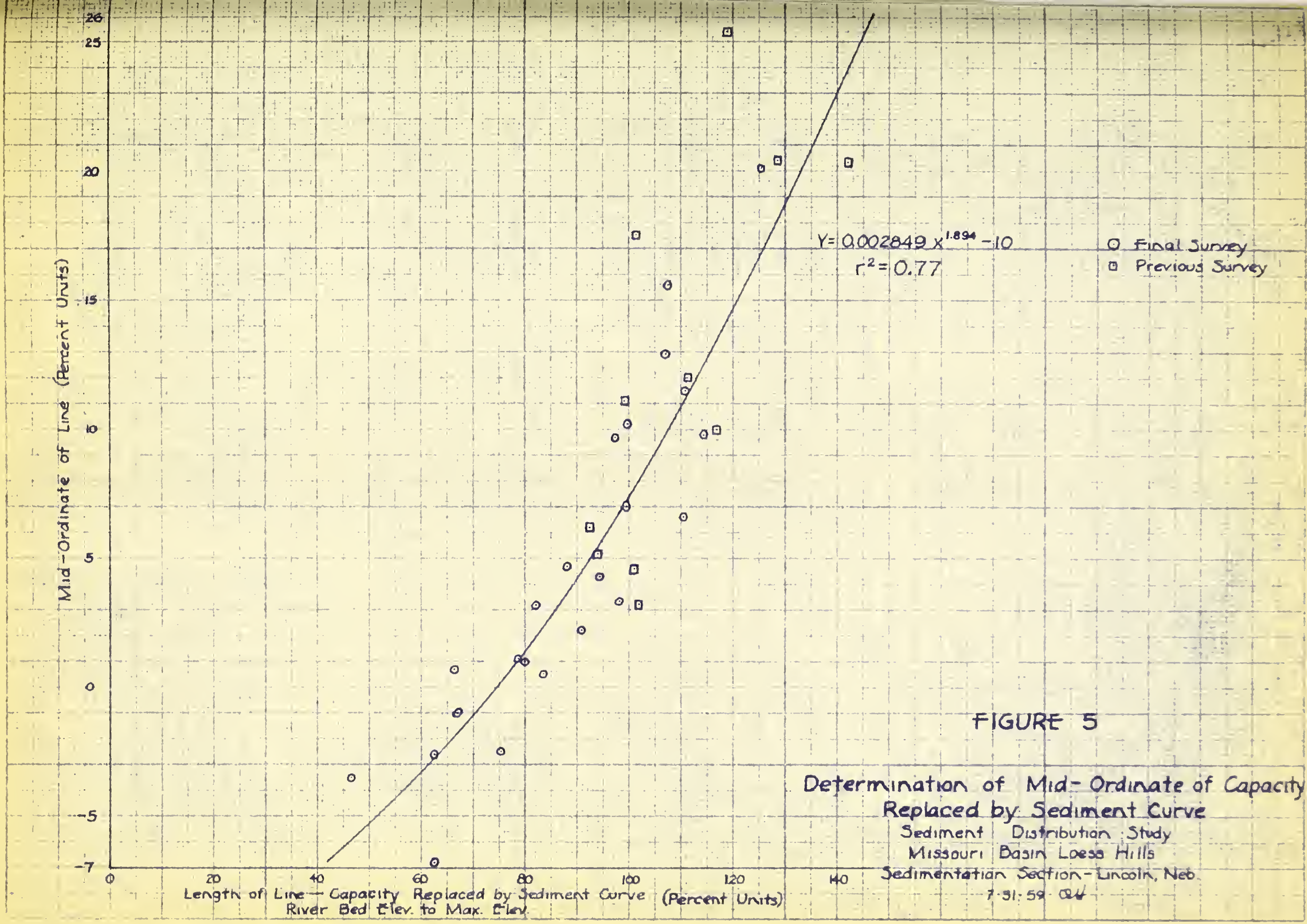

FIGURE 5

Determination of Mid-Ordinate of Capacity
Replaced by Sediment Curve
Sediment Distribution Study
Missouri Basin Loess Hills
Sedimentation Section - Lincoln, Neb.
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The Sediment Distribution curves are occasionally erratic at low degrees of storage depletion, but they usually become more uniform as additional sediment is deposited in the pond. As the pond fills up with sediment this curve approaches the Stage Capacity curve. Since the storage capacity at low elevations is restricted by the channel topography the sediment volume at low elevations is also restricted. For this reason, the Sediment Distribution curve at the lower elevations for later surveys always falls between the curve for earlier surveys and the Stage-Capacity curve. The sediment at this elevation becomes a smaller percentage of the total. The Sediment Distribution curve is not affected abruptly at the crest elevation of the drop inlet as was originally presumed. The flatter more horizontal segments of these curves indicate the elevations between which the highest percentages of sediment are deposited. The more vertical segments indicate segments of lower percentages of sediment accumulation.

The Capacity Replaced by Sediment or storage depletion curves show the percent of accumulated original capacity to any percent of depth, now occupied by sediment. The highest percent of depth which has 100% of its capacity replaced by sediment, is the location or elevation of the river bed or bottom of reservoir at the date of survey. As the reservoir fills up and storage depletion is greater the river bed elevation also becomes higher. As this takes place the distance on this curve between the river bed and at 100% depth becomes shorter and the curve usually becomes straighter. It is believed that the curved portion of this curve can be drawn in sufficiently accurate if the mid-point is provided.

As mentioned previously, the Sediment Distribution curve can be computed from the Original Stage Capacity and the Capacity Replaced By Sediment curves. Use the formula, Sediment Distribution for a certain elevation = (value from Stage-Capacity curve at the elevation) X (value from Capacity Replaced By Sediment curve at the elevation), ÷ by (total storage depletion). Using Figure 2 as an example, the sediment distribution in percent at the 68% depth level would be 39.3 X 59.4 ÷ 25.8 = 90.5.

Evaluation of Results

Data from the 34 sedimentation surveys on 23 reservoirs evaluated in this study were utilized in a multiple regression analysis to determine the estimated rise in the river bed elevation in a floodwater retarding structure. Data actually used in the analyses were collected from Table 6 and Figures 6 to 28 and shown in Table 2. The rise in the river bed elevation was expressed as the Percent Original Reservoir Depth Filled With Sediment.

This is the dependent variable Y. The most efficient equation developed is No. 7 which is $Y = 22.6 + 0.886D - 81.2N - 0.175S + 0.494W$. D is Total Original Storage Depletion in percent. N is the Original "n" Value, which is a topography factor and has been explained. S is the Total Storage Capacity in acre feet. W is the Sediment Sample Volume Weight in pounds per cubic foot. Statistical data on this equation are given in Table 5. The independent variables used in the equation are significant at about the one percent level, and the other tests also indicate that the variables used are important ones. The Coefficient of Determination, R^2, for the equation is 0.91. A comparison of the actual values of the dependent variable with the computed or predicted values is shown in Figure 3.

Figure 4, Remaining Storage - Depth Ratio Curve, can be used to help draw a Capacity Replaced by Sediment curve and also to determine the portion of the total remaining storage that exists above the crest elevation of the drop inlet. The coefficient of determination r^2 for this curve is 0.95, which indicates an excellent relationship. This curve cannot be used when all of the remaining storage is located above the drop inlet.

Figure 5, Determination of Mid-Ordinate of Capacity Replaced by Sediment Curve, can also be used to help draw a Capacity Replaced by Sediment Curve. As the plottings show the relationship is fairly good, the coefficient of determination being 0.77. However, when this is used with the curve described in the preceding paragraph, the results should be very good.

Application of Results

Using the preceding material, the following steps can be utilized to determine the elevation at which to place the crest of a drop inlet for a floodwater retarding pond or reservoir in the Missouri Basin loess hills.

1. Estimate the probable sediment yield for the watershed above the proposed structure. If this figure will vary because a complete conservation program has not yet been applied, do not ignore this fact.

2. Estimate the trap efficiency for the structure. This figure will also probably vary.

3. Compute the annual amounts of sediment accumulation in the pond or reservoir. This is the product of sediment yield and trap efficiency (Step 1 x Step 2).

4. If the design criteria are such that the pond or reservoir must be capable of containing or retarding a certain amount of runoff after a given period of life of the reservoir (say 50 years) then compute the sediment accumulation in the reservoir during that period of time (step 3 x time).

5. The total capacity of the reservoir must then be equal to or greater than the total of the sediment accumulation (step 4) plus the required capacity for runoff.

6. Having the total original capacity and the total sediment that will accumulate in the reservoir, proceed to determine the variables of Equation 7. Total Original Storage Depletion, D, will be step 4 divided by step 5.

7. Original "n" Value, N, can be determined for a reservoir site as follows:

   a. Using log-log paper plot the reservoir depths as the ordinates (Y axis) versus the reservoir capacities as the abscissas (X axis).

   b. Draw a straight line through these points.

   c. Determine the slope of the line using a scale rather than reading measurements in log units. The slope is the "n" value.

8. Total Storage Capacity, S, is the estimated remaining capacity in acre feet at this date (step 5 - step 4).

9. Sediment Sample Volume Weight, W, or specific weight, in Lb/Cu. Ft., will have to be obtained from the average of the volume weights of sediment samples from submersed sediments in ponds and reservoirs in the immediate vicinity.

10. Compute Y, Original Reservoir Depth Filled With Sediment, using the above four items and equation $Y = 0.886D - 81.2N - 0.175S + 0.494W + 22.6$. The answer is the percent of the total depth from the original bottom that will have been filled up with sediment. In other words, it indicates how much the river bed has risen and the elevation where the crest of the drop inlet should be placed.

If knowledge as to the sediment distribution is also desired, proceed as follows.

1. Plot the original Stage-Capacity curve in percents, as in Figure 2.

2. Plot the percent of total original depth filled with sediment from step 10 of the previous set. This is the highest vertical point at the 100% point on the X axis.

3. Plot the storage depletion at the elevation of maximum capacity.

4. Draw a straight line between the points plotted in steps 2 and 3 above and find the mid-point. From the length of the straight line of step 4 (using the same units of measurement) and Figure 5, compute the mid-ordinate and plot it from the mid-point of the straight line.

5. Multiply original capacity by the storage depletion and obtain the storage lost to sediment. Subtract this from the original capacity to obtain the storage capacity remaining. Using the riverbed elevation determined in step 10 of the previous set, compute the depth ratio needed in Figure 4. From this ratio and Figure 4 obtain the percent of the total remaining storage that exists between the spillways. This figure subtracted from 100% gives the percent of remaining storage located below the drop inlet. This value multiplied by the total reservoir capacity remaining (determined above) gives the acre feet capacity remaining below the drop inlet.

   Determine the original capacity below the drop inlet by multiplying the original capacity by the percent of the original storage below the inlet (from stage-storage curve). Divide this original capacity into the capacity remaining (determined in the last step of the previous paragraph) to find the percent of the original storage below the drop inlet that remains. This percent subtracted from 100% gives the percent depletion up to the crest of the drop inlet. This computed point should be plotted at the crest elevation. This point will be a more accurate one than that determined in step 4 and, therefore, should be given the most weight if these two points plot near each other.

6. Using the characteristic shapes of the Capacity Replaced By Sediment curves of Figures 6 to 28 and the four points established above, sketch in the Capacity Replaced By Sediment curve.

7. Planimeter the total area above this curve and also the area outlined by this curve that is located above the crest elevation of the drop inlet. The percent of the total area that is located above the crest of the inlet, determined in this manner, should approximate the percent as determined by using Figure 4. This figure can only be used while capacity remains below the drop inlet. Adjust the sketched curve of step 6 until these percentage figures are quite near each other.

8. From this curve (step 7), Capacity Replaced By Sediment, and the Original Stage Capacity curve (step 1) compute points for the Sediment Distribution curve. This can be done in accordance with the method described in the paragraph just prior to the section, "Evaluation of Results."

It should be restated that this procedure applies to floodwater retarding structures in the Missouri Basin loess hills only. No efforts have been made to compare these results with the data in any other area. The limits of the data used in this report should be kept in mind. The material presented here should not be applied to structures having values for important parameters that are in excess of the data used herein.

SUMMARY

This is a study of the sediment distribution in 23 floodwater retarding structures in the Missouri Basin loess hills. Considerable data were obtained on these ponds and reservoirs and Stage-Capacity, Capacity Replaced by Sediment and Sediment Distribution curves were drawn for each pond. These curves are discussed in detail, compared with one another, and various findings pointed out.

After making numerous graphical analyses, the multiple regression method was used to derive an equation for computing the elevation at which the crest of the drop inlet for a floodwater retarding structure should be located. The variables used in this equation are (1) Total Original Storage Depletion, (2) Original "n" Value, (3) Total Storage Capacity, and (4) Sediment Sample Volume Weight. A step by step procedure is given for obtaining the variables and computing the elevation.

Curves are also presented and a description given for drawing the Capacity Replaced by Sediment curve. Using this and the Original Stage-Capacity curve a method is described for drawing a Sediment Distribution curve. A step by step procedure is also given for this entire process.

The material and results presented here have not been compared with or tried on the data from other areas. Therefore, these findings should be limited in application to floodwater retarding structures in the Missouri Basin loess hills only.

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RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION

FILE 8.27

COMPUTATIONS OF: Sediment Distribution Study — TABLE 6-1

Reservoir Capacity and Sediment Information

(1) Data Summary Sheet	(2) Name	(3) County	(4) Stream System	(5) Date of Survey (Mo.&Yr.)	(6) Period between Surveys (Years)	(7) Sed Samples (No.)	(8) Ave. Sed. Sample Vol. Wt. (lb/ft³)	(9) Total Storage Capacity (AF)	(10) Remain Capacity Retent. Pool (AF)	(11) Remain. Capacity Detent. Pool (AF)	(12) Remain Storage between Spillways (%)	(13) Origin. Storage Lost Retent. Pool (AF)	(14) Origin Storage Lost Detent. Pool (AF)	(15) Total Storage Capacity Lost (AF)	(16) Total Average Annual Capacity Lost (AF/mi.²/Yr)	(17) Total Origin. Storage Depletion (%)
31-2	Carl	Montgomery	West	6/38	-	-	-	16.47	9.46	7.01	42.56	0	0	0	0	0
	Chinquest		Nodaway	5/49	10.9	3	50.0	8.52	2.59	5.93	69.60	6.87	1.08	7.95	4.10	48.27
31-3	L. H.	Atchison	Tarkio	7/39	-	-	-	68.57	31.80	36.77	53.62	0	0	0	0	0
	Fuelling	(Missouri)	Creek	5/49	9.8	3	62.9	33.50	1.93	31.57	94.24	29.87	5.20	35.07	3.44	51.14
35-1	Otto Baak	Crawford	Soldier	9/44	-	-	-	22.45	6.91	15.54	69.22	0	0	0	0	0
			River	4/49	4.6	3	54.8	16.81	2.28	14.53	86.44	4.63	1.01	5.64	7.81	25.12
35-2	Fred Brown	Harrison	Willow River	6/41	-	-	-	22.93	11.89	11.04	48.15	0	0	0	0	0
				5/49	7.9	3	63.8	15.12	4.61	10.51	69.51	7.28	0.53	7.81	10.19	34.06
35-3	Wm. Esbeck	Cass	Elkhorn	5/40	-	-	-	19.87	12.60	7.27	36.59	0	0	0	0	0
			Creek	5/49	9.0	3	56.1	11.19	4.51	6.68	59.70	8.09	0.59	8.68	4.73	43.68
35-4	C.& A. Evers	Crawford	Boyer River	12/38	-	-	-	28.26	6.63	21.63	76.54	0	0	0	0	0
	(Lower)			4/49	10.3	3	68.4	20.96	1.26	19.70	93.99	5.37	1.93	7.30	5.45	25.83
35-5	C.& A. Evers	Crawford	Boyer River	3/39	-	-	-	3.26	1.90	1.36	41.72	0	0	0	0	0
	(Upper)			4/49	10.1	3	71.6	1.19	0.22	0.97	81.51	1.68	0.39	2.07	4.66	63.50
35-6	Charles	Crawford	Boyer River	5/45	-	-	-	27.30	12.63	14.67	53.74	0	0	0	0	0
	Fienhold			4/49	3.9	3	63.1	17.45	3.48	13.97	80.06	9.15	0.70	9.85	5.94	36.08
35-7A	C. T. Gadd	Montgomery	East Nishna-botna River	12/40	-	-	-	14.48	7.43	7.05	48.69	0	0	0	0	0
				5/49	8.4	3	63.0	12.82	5.87	6.95	54.21	1.56	0.10	1.66	2.50	11.46
				6/52	3.1	3	57.3	11.98	5.25	6.73	56.18	2.18	0.32	2.50	2.75	17.27

All Counties in Iowa, except those specifically noted.

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COMPUTATIONS OF: Sediment Distribution Study

TABLE 6-2

Reservoir Data — Watershed Data

(1) Data Summary Sheet	(5) Date of Survey (Mo.& Yr.)	(18) Elev. of Max. Capacity Area (Acres)	(19) Length of Reserv. (ft)	(20) "n" Values (Slope on log log of Depth vs. Cap.)	(21) Reserv. Shape Factor	(22) Contrib. Drainage Area (Sq. Miles)	(23) Capacity Water-shed Ratio (AF/mi²)	(24) River-bed Elev. (ft)	(25) Primary Spillway Elev. (ft)	(26) Elev. of Max. Capacity (ft)	(27) Size of Lower Spillway (Sq. ft)	(28) Detention Time (Min)	(29) Basin Length (ft)	(30) Drainage Area Shape Factor	(31) Time of Concentration (Min)	(32) Total No. of Precip. Events ≥0.50 in	(33) Total Precip for Events ≥0.50 in (Inches)
31-2	6/38	2.82	675	0.47	0.470	0.178	92.5	86.1	100.0	103.2	16	0	3700	0.532	15	235.3	241.3
	5/49	2.49					47.9	95.7	100.0	103.2							
31-3	7/39	7.76	3260	0.37	0.040	1.04	65.93	85.2	100.0	106.2	36	42	8900	0.598	43.0	227.3	246.0
	5/49	7.76					32.21	95.9	100.0	106.2							
35-1	9/44	3.17	700	0.38	0.459	0.157	142.99	87.8	100.0	107.4	4.91	432	3130	0.736	17.4	74.3	74.7
	4/49	3.17					107.07	95.5	100.0	107.4							
35-2	6/41	2.62	660	0.49	0.480	0.097	236.39	85.1	100.0	104.8	3.14	210	3100	0.645	10	145.1	146.8
	5/49	2.62					155.88	95.5	100.0	104.8							
35-3	5/40	3.37	380	0.49	0.399	0.204	97.40	86.9	100.0	102.5	30.0	0	3400	0.835	14.0	185.8	201.1
	5/49	3.37					54.85	95.2	100.0	102.5							
35-4	12/38	4.58	875	0.41	0.353	0.130	217.38	91.8	100.0	106.8	36.0	0	3200	0.468	12	190.8	194.8
	4/49	4.58					161.23	98.4	100.0	106.8							
35-5	3/39	.810	160	0.46	0.460	0.044	74.1	87.4	100.0	102.2	0.785	0	3170	0.918	12	190.0	196.1
	4/49	.798					27.0	98.2	100.0	102.2							
35-6	5/45	3.48	1405	0.47	0.070	0.425	64.24	84.5	100.0	106.0	36.0	0	4538	0.764	25.2	70.3	81.5
	4/49	3.48					41.1	95.7	100.0	106.0							
35-7A	12/40	2.09	550	0.49	0.383	0.079	183.3	88.8	100.0	104.2	1.23	384	2100	0.890	13.0	258.1	272.7
	5/49	2.09					162.3	93.3	100.0	104.2							
	6/52	2.09					151.6	94.0	100.0	104.2							

RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION

FILE 829

COMPUTATIONS OF: Sediment Distribution Study — Reservoir Capacity and Sediment Information

TABLE 6-3

(1) Data Summary Sheet	(2) Name	(3) County	(4) Stream System	(5) Date of Survey (Mo & Yr.)	(6) Period between Surveys (Years)	(7) Sed Samples (No.)	(8) Ave. Sed Sample Vol. Wt. (lb/ft^3)	(9) Total Storage Capacity (A.F.)	(10) Remain. Capacity Retent. Pool (A.F.)	(11) Remain Capacity Detent. Pool (A.F.)	(12) Remain Storage between Spillways (%)	(13) Origin. Storage Lost Retent. Pool (A.F.)	(14) Origin. Storage Lost Detent. Pool (A.F.)	(15) Total Storage Capacity Lost (A.F.)	(16) Total Average Annual Capacity Lost (A.F./mi^2/yr)	(17) Total Origin. Storage Depletion (%)
35-8	Otto Goslar	Crawford	Middle	5/40	-	-	-	13.69	10.18	3.51	25.64	0	0	0	0	0
			Soldier Riv.	3/49	8.8	3	69.1	11.80	8.29	3.51	29.75	1.89	0	1.89	1.49	13.81
35-10	Fred Hollrah	Crawford	Willow Creek	8/44	-	-	-	37.53	18.98	18.55	49.42	0	0	0	0	0
				3/49	4.6	3	57.6	31.14	12.76	18.38	59.02	6.22	0.17	6.39	6.40	17.03
35-12A	Emma	Crawford	Boyer River	5/42	-	-	-	15.28	12.69	2.59	16.95	0	0	0	0	0
	LaFrontz			4/49	6.9	3	56.4	10.38	7.86	2.52	24.28	4.83	0.07	4.90	4.67	32.07
				7/53	4.2	3	62.0	9.47	6.93	2.54	26.82	5.76	0.05	5.81	3.44	38.02
35-13	Jensen-	Otoe	Little	11/36	-	-	-	41.18	23.68	17.50	42.50	0	0	0	0	0
	O'Neil	(Nebraska)	Nemaha	11/48	12.0	3	54.73	31.18	16.79	14.39	46.15	6.89	3.11	10.00	4.32	24.28
35-14	Peterson	Otoe	Little	10/36	-	-	-	3.87	2.06	1.81	46.77	0	0	0	0	0
		(Nebraska)	Nemaha	11/48	12.1	3	61.01	1.74	0.16	1.58	90.80	1.90	0.23	2.13	2.38	55.04
35-15A	Alfred Lage	Crawford	Elk Creek	6/41	-	-	-	11.23	5.70	5.53	49.24	0	0	0	0	0
				4/49	7.8	3	54.0	8.56	3.31	5.25	61.33	2.39	0.28	2.67	1.79	23.77
				6/52	3.2	2	53.3	7.14	2.23	4.91	68.77	3.47	0.62	4.09	1.95	36.42
35-16A	Herman Lage	Crawford	Elk Creek	7/41	-	-	-	12.07	8.24	3.83	31.73	0	0	0	0	0
				4/49	7.8	3	55.1	10.81	6.68	4.13	38.21	1.56	+0.30	1.26	4.48	10.44
				6/52	3.2	3	49.3	8.96	5.15	3.81	42.52	3.09	0.02	3.11	7.85	25.77
35-17A	Howard	Crawford	Boyer River	7/44	-	-	-	16.44	3.92	12.52	76.16	0	0	0	0	0
	Mattson			4/49	4.8	3	69.0	12.56	1.91	10.65	84.79	2.01	1.87	3.88	8.25	23.60
				7/53	4.2	3	87.1	8.91	0	8.91	100.0	3.92	3.61	7.53	8.54	45.80

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RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION

FILE 8.30

COMPUTATIONS OF: Sediment Distribution Study

TABLE 6-4

Reservoir Data													Watershed Data				
(1) Data Summary Sheet	(5) Date of Survey (Mo & Yr)	(18) Elev. of Max. Capacity Area (Acres)	(19) Length of Reserv. (ft)	(20) "n" Values (Slope on log log of Depth vs. Cap.)	(21) Reserv. Shape Factor	(22) Contrib. Drainage Area (Sq. Miles)	(23) Capacity Watershed Ratio (AF/Mi^2)	(24) River-bed Elev. (ft)	(25) Primary Spillway Elev. (ft)	(26) Elev. of Max. Capacity (ft)	(27) Size of Lower Spillway (Sq. ft)	(28) Detention Time (Min)	(29) Basin Length (ft)	(30) Drainage Area Shape Factor	(31) Time of Concentration (Min.)	(32) Total No. of Precip Events ≥0.50 in	(33) Total Precip. for Events ≥0.50 in. (Inches)
35-8	5/40	2.19	470	0.41	0.330	0.144	95.07	85.0	100.0	101.8	17.5	0	2100	0.712	9.0	163.8	162.7
	3/49	2.19					81.94	90.3	100.0	101.8							
35-10	8/44	4.71	1170	0.42	0.232	0.217	172.9	80.1	100.0	105.2	7.07	148	5100	0.545	21	80.9	79.1
	3/49	4.71					143.5	87.1	100.0	105.2							
35-12A	5/42	2.07	420	0.44	0.390	0.152	100.5	82.0	100.0	101.4	7.07	0	2800	0.866	12.0	234.1	249.3
	4/49	2.04					68.3	88.7	100.0	101.4							
	7/53	2.04					62.3	92.6	100.0	101.4							
35-13	11/36	6.06	700	0.40	0.614	0.193	213.37	80.6	100.0	103.3	4	201	2970	0.604	15	238.6	245.5
	11/48	5.12					161.56	90.5	100.0	103.3	4						
35-14	10/36	0.83	275	0.47	0.601	0.074	52.30	91.7	100.0	102.9	4	28	1550	0.811	7.5	238.2	245.2
	11/48	0.82					23.51	99.2	100.0	102.9	4						
35-15A	6/41	2.35	860	0.42	0.160	0.191	58.80	89.6	100.0	103.0	25.0	0	3200	0.620	13.5	232.5	244.3
	4/49	2.31					44.81	95.0	100.0	103.0							
	6/52	2.31					37.38	96.6	100.0	103.0							
35-16A	7/41	1.63	420	0.62	0.503	0.036	335.28	87.5	100.0	102.8	0.54	321	1500	0.760	6.0	231.6	244.0
	4/49	1.63					300.28	89.1	100.0	102.8							
	6/52	1.63					248.89	90.2	100.0	102.8							
35-17A	7/44	2.72	400	0.48	0.302	0.098	167.75	93.2	100.0	106.0	9	150	2100	0.917	7.2	192.8	199.5
	4/49	2.72					128.16	96.5	100.0	106.0							
	7/53	2.72					90.92	100.7	100.0	106.0							

RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
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SOIL AND WATER CONSERVATION RESEARCH DIVISION

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COMPUTATIONS OF: Sediment Distribution Study

Reservoir Capacity and Sediment Information

TABLE 6-5

(1) Data Summary Sheet	(2) Name	(3) County	(4) Stream System	(5) Date of Survey (Mo. & Yr.)	(6) Period between Surveys (Years)	(7) Sed. Sample (No.)	(8) Ave. Sed. Sample Vol. Wt. (lb/ft³)	(9) Total Storage Capacity (A.F.)	(10) Remain Capacity Retent. Pool (A.F.)	(11) Remain Capacity Detent. Pool (A.F.)	(12) Remain Storage between Spillways (%)	(13) Origin. Storage Lost Retent. Pool (A.F.)	(14) Origin. Storage Lost Detent. Pool (A.F.)	(15) Total Storage Capacity Lost (A.F.)	(16) Total Average Annual Capacity Lost (A.F./mi²/yr)	(17) Total Origin. Storage Depletion %
35-18A	Wilbur	Crawford	Boyer River	11/44	-	-	-	43.80	11.04	32.76	74.79	0	0	0	0	0
	Meyer			4/49	4.4	3	58.0	37.33	6.40	30.93	82.86	4.64	1.83	6.47	5.02	14.77
				6/52	4.2	3	63.6	34.63	3.78	30.85	89.08	7.26	1.91	9.17	3.64	20.94
35-19A	Max Miller	Potta-	West Nishna-	11/41	-	-	-	48.83	9.50	39.33	80.54	0	0	0	0	0
	No. 1	wattamie	botna River	5/49	7.5	3	64.9	35.75	1.35	34.40	96.22	8.15	4.93	13.08	8.00	26.79
				6/52	3.1	3	69.5	32.10	0.12	31.98	99.63	9.38	7.35	16.73	7.24	34.26
35-20A	Max Miller	Potta-	West Nishna-	11/41	-	-	-	53.19	16.29	36.90	69.37	0	0	0	0	0
	No. 5	wattamie	botna River	5/49	7.5	3	69.2	41.94	7.45	34.49	82.24	8.84	2.41	11.25	6.58	21.15
				6/52	3.1	3	73.1	41.06	6.70	34.36	83.68	9.59	2.54	12.13	5.02	22.81
35-21A	Barney	Crawford	Boyer River	10/44	-	-	-	45.97	17.62	28.35	61.67	0	0	0	0	0
	Mundt			4/49	4.5	3	54.0	33.08	8.05	25.03	75.66	9.57	3.32	12.89	8.68	28.04
				6/52	3.2	3	53.3	29.22	4.79	24.43	83.61	12.83	3.92	16.75	6.59	36.44
35-22A	Tracy North	Crawford	Boyer River	11/39	-	-	-	48.64	36.60	12.04	24.75	0	0	0	0	0
				3/49	9.3	3	52.4	40.04	28.35	11.69	29.20	8.25	0.35	8.60	3.89	17.68
				7/53	4.3	18	56.5	37.41	25.93	11.48	30.69	10.67	0.56	11.23	3.47	23.09
36-2A	C. A. Stiles	Cherokee		12/40	-	-	-	78.00	52.5	25.5	32.69	0	0	0	0	0
				9/50	9.8	3	47.3	69.1	44.5	24.6	35.60	8.00	0.90	8.90	1.59	11.41
				2/53	3.9	5	57.8	67.7	43.3	24.4	36.04	9.20	1.10	10.30	1.31	13.20

RECORD OF COMPUTATIONS

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION

FILE 8.32

COMPUTATIONS OF: Sediment Distribution Study

TABLE 6-6

Reservoir Data | Watershed Data

(1) Data Summary Sheet	(5) Date of Survey (Mo. & Yr.)	(18) Elev. of Max. Capacity Area (Acres)	(19) Length of Reserv. (ft.)	(20) "n" Values (Slope on log log of Depth vs. Cap.)	(21) Reserv. Shape Factor	(22) Contrib. Drainage Area (Sq. Miles)	(23) Capacity Watershed Ratio (Af/mi.^{2})	(24) River-bed Elev. (ft.)	(25) Primary Spillway Elev. (ft)	(26) Elev. of Max. Capacity (ft.)	(27) Size of Lower Spillway (Sq. ft.)	(28) Detention Time (Min.)	(29) Basin Length (ft.)	(30) Drainage Area Shape Factor	(31) Time of Concentration (Min.)	(32) Total No. of Precip. Events ≥0.50 in.	(33) Total Precip. for Events ≥0.50 in (Inches)
35-18A	11/44	6.38	1250	0.37	0.226	0.293	149.49	88.2	100.0	108.0	9.62	124	4200	0.758	16.0	154.0	171.1
	4/49	6.38					127.41	93.5	100.0	108.0							
	6/52	6.38					118.19	96.4	100.0	108.0							
35-19A	11/41	8.24	775	0.51	0.422	0.218	223.99	94.0	100.0	107.5	3.14	364	2300	0.794	5.0	232.2	236.5
	5/49	8.24					163.99	98.6	100.0	107.5							
	6/52	8.24					147.25	99.6	100.0	107.5							
35-20A	11/41	6.76	485	0.42	0.478	0.228	233.99	87.2	100.0	108.1	3.14	401	3400	0.372	12.0	231.8	236.0
	5/49	6.76					183.95	95.9	100.0	108.1							
	6/52	6.76					180.09	96.5	100.0	108.1							
35-21A	10/44	6.23	815	0.36	0.467	0.330	139.30	86.2	100.0	105.9	9.6	164	5000	0.742	18.0	156.8	170.9
	4/49	6.23					100.24	94.4	100.0	105.9							
	6/52	6.23					88.55	97.1	100.0	105.9							
35-22A	11/39	5.37	990	0.41	0.385	0.238	204.37	80.4	100.0	102.4	16.0	88	5000	0.590	18.0	281.5	290.6
	3/49	5.37					168.24	86.8	100.0	102.4							
	7/53	5.37					157.18	88.5	100.0	102.4							
36-2A	12/40	13.46	1460	0.43	0.460	0.572	136.34	87.0	100.0	102.2	12.25	282	5100	0.862	25	222.0	227.8
	9/50	13.21					120.79	89.2	100.0	102.2							
	2/53	13.24					118.34	89.5	100.0	102.2							

Form 29
1958

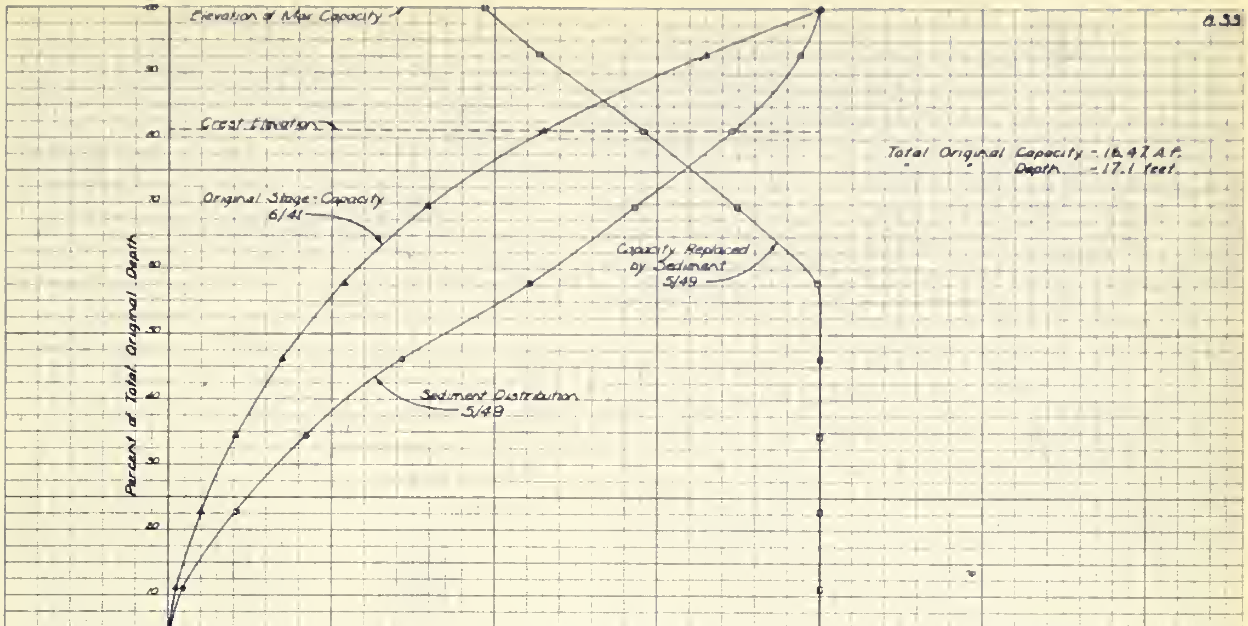


FIGURE 6

CARL CHINQUIST (IOWA) 31-2

Sedimentation and Capacity Curves

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Neb.

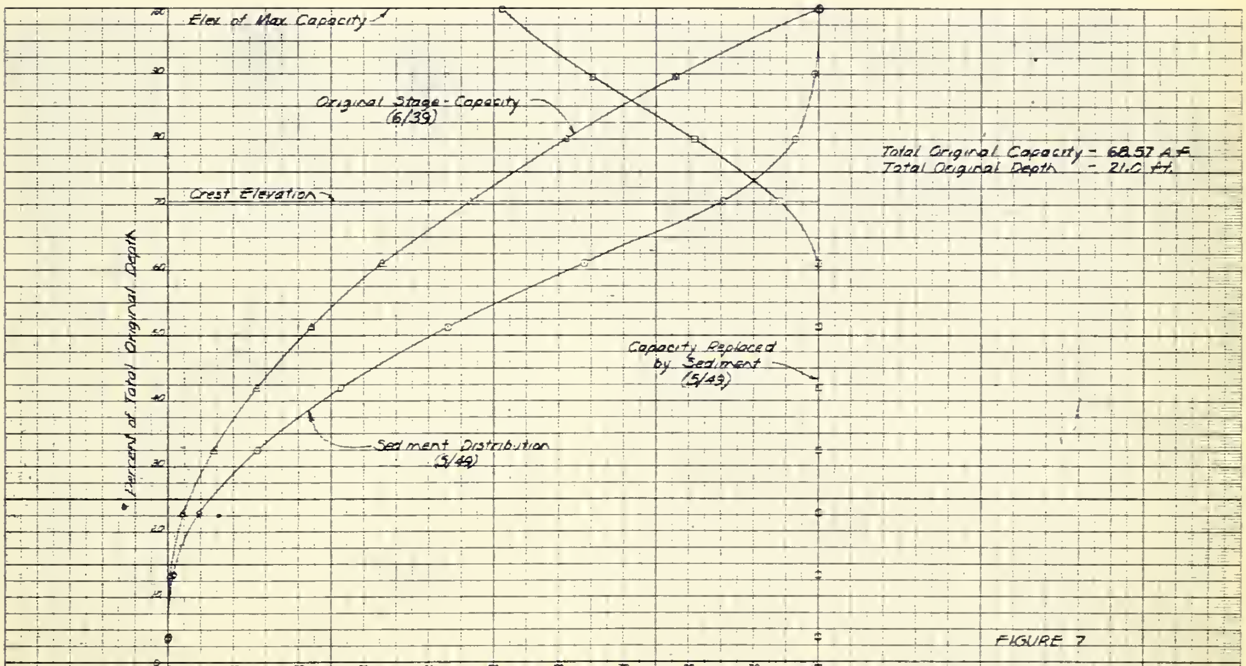


FIGURE 7

L.H. FUELLING (Missouri) 31-3

SEDIMENTATION and CAPACITY CURVES

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

5/5/39

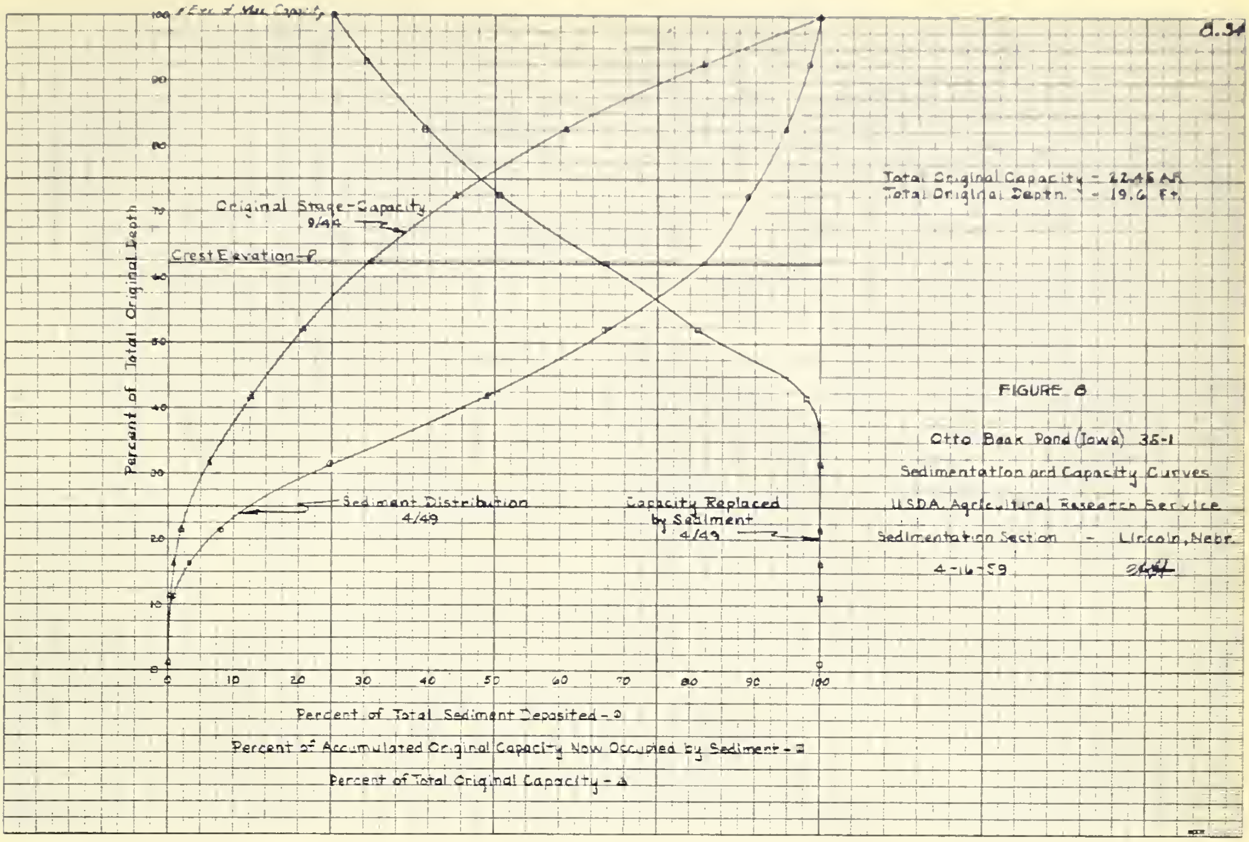


FIGURE 8

Otto Baak Pond (Iowa) 35-1

Sedimentation and Capacity Curves

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.

4-16-59

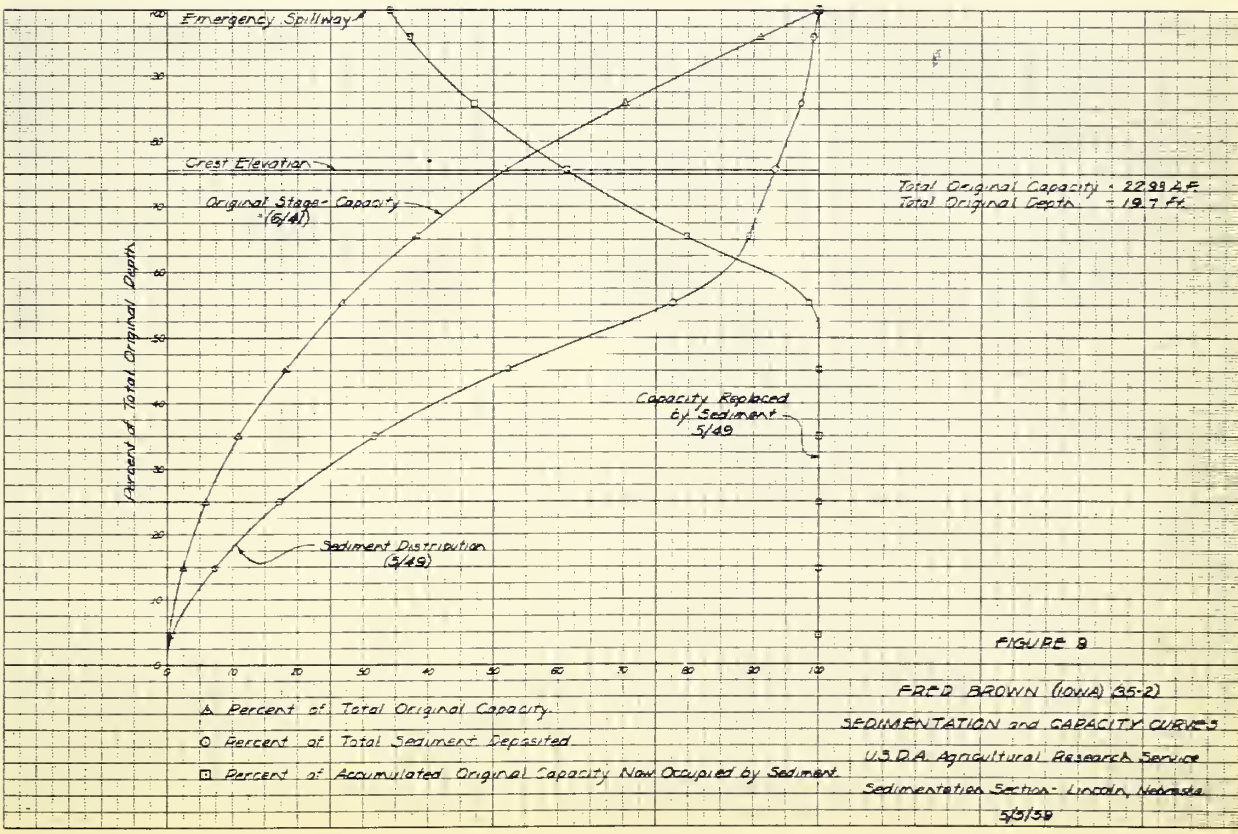


FIGURE 9

FRED BROWN (IOWA) (35-2)

SEDIMENTATION and CAPACITY CURVES

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

5/5/59

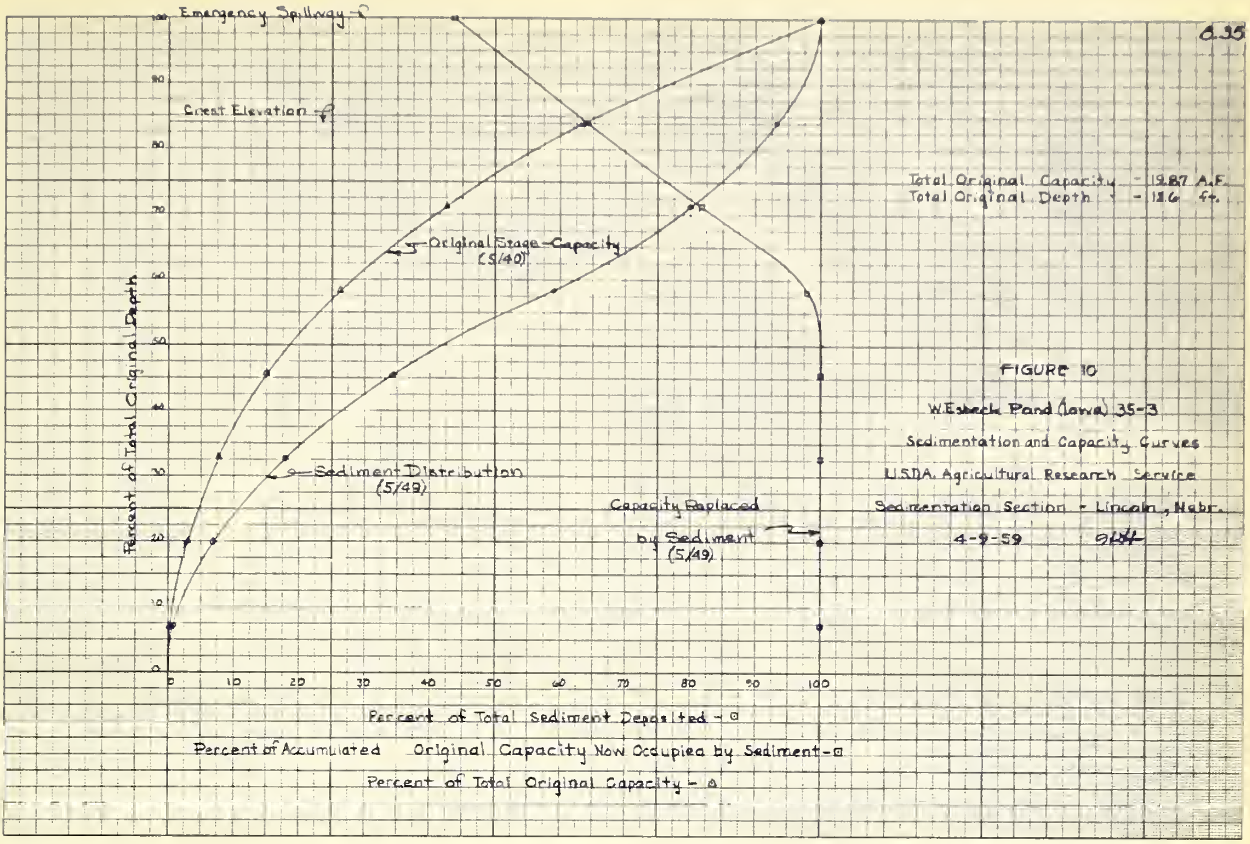


FIGURE 10

W. Esbeck Pond (Iowa) 35-3

Sedimentation and Capacity Curves

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.

4-9-59

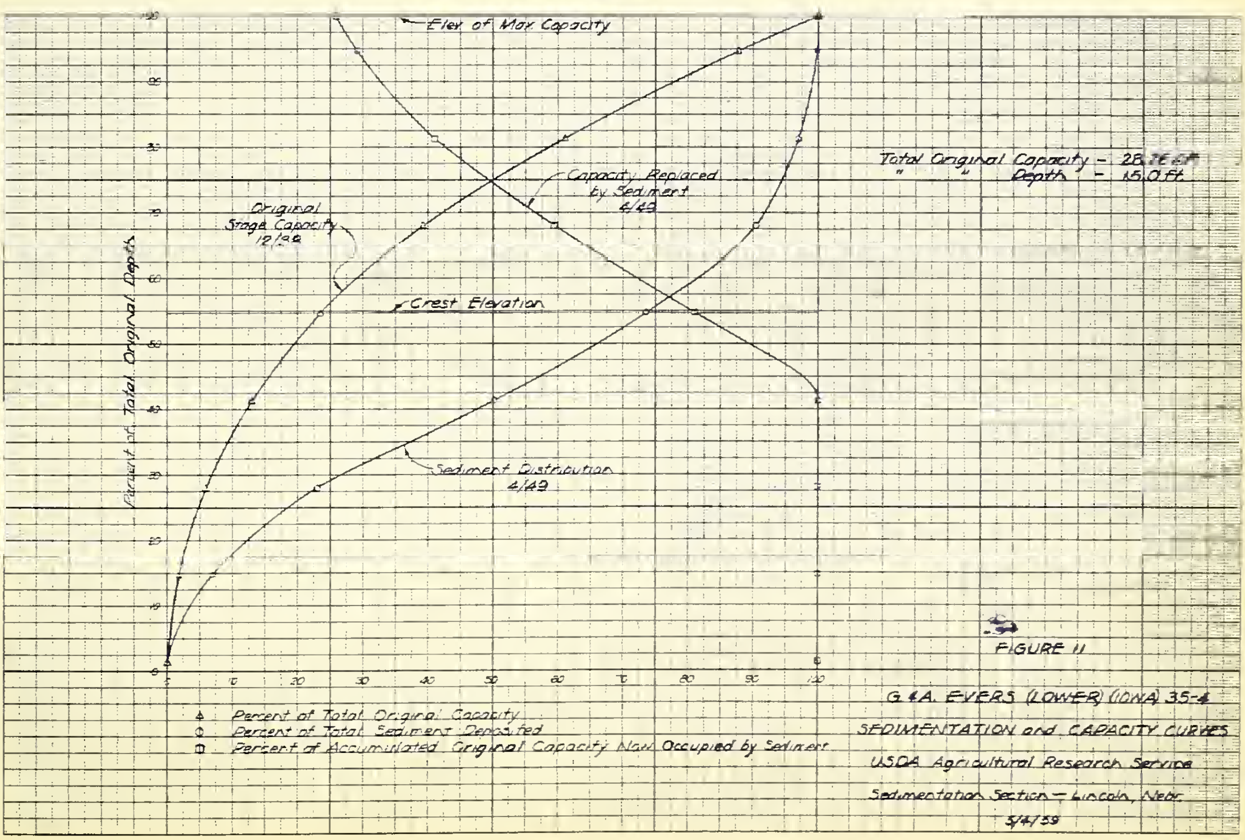


FIGURE 11

G & A. EVERS (LOWER) (IOWA) 35-4

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/4/59

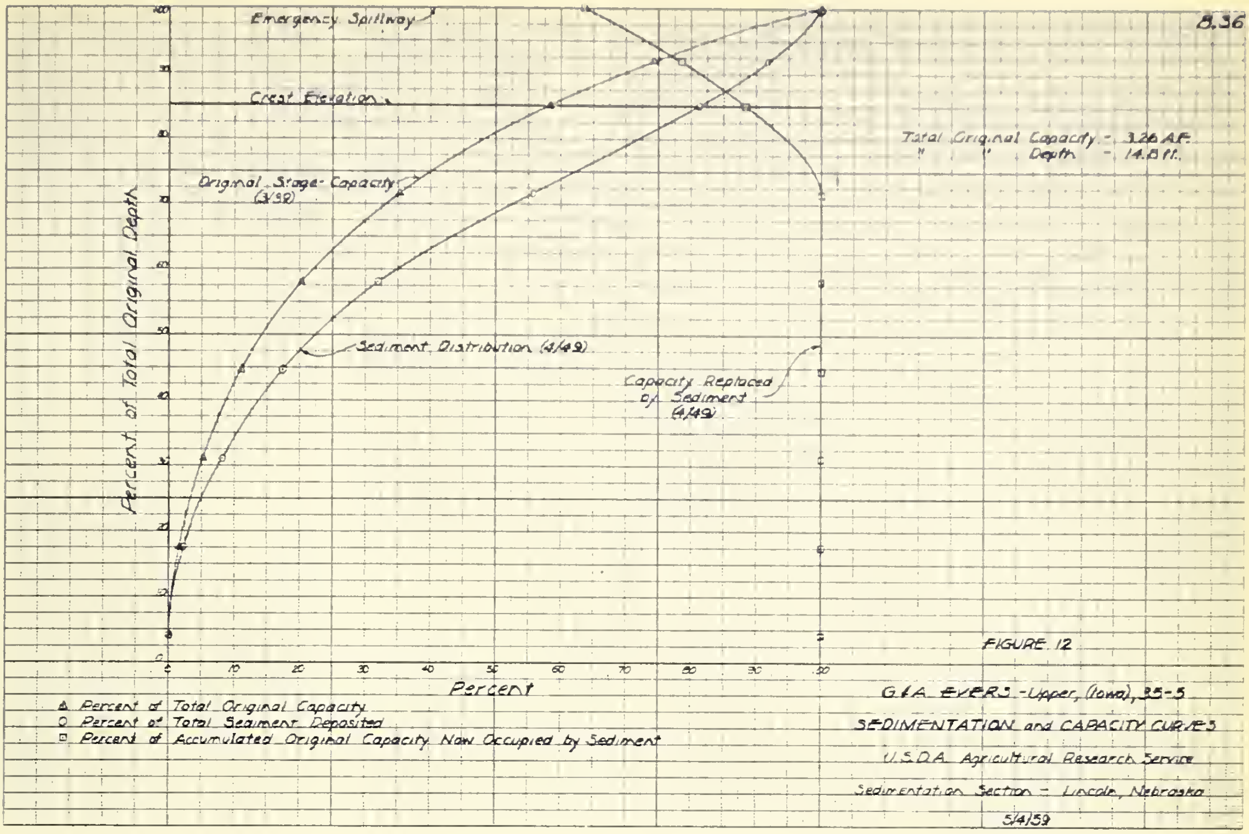


FIGURE 12

G & A EVERS - Upper, (Iowa), 35-5

SEDIMENTATION and CAPACITY CURVES

U.S.D.A. Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

5/4/59

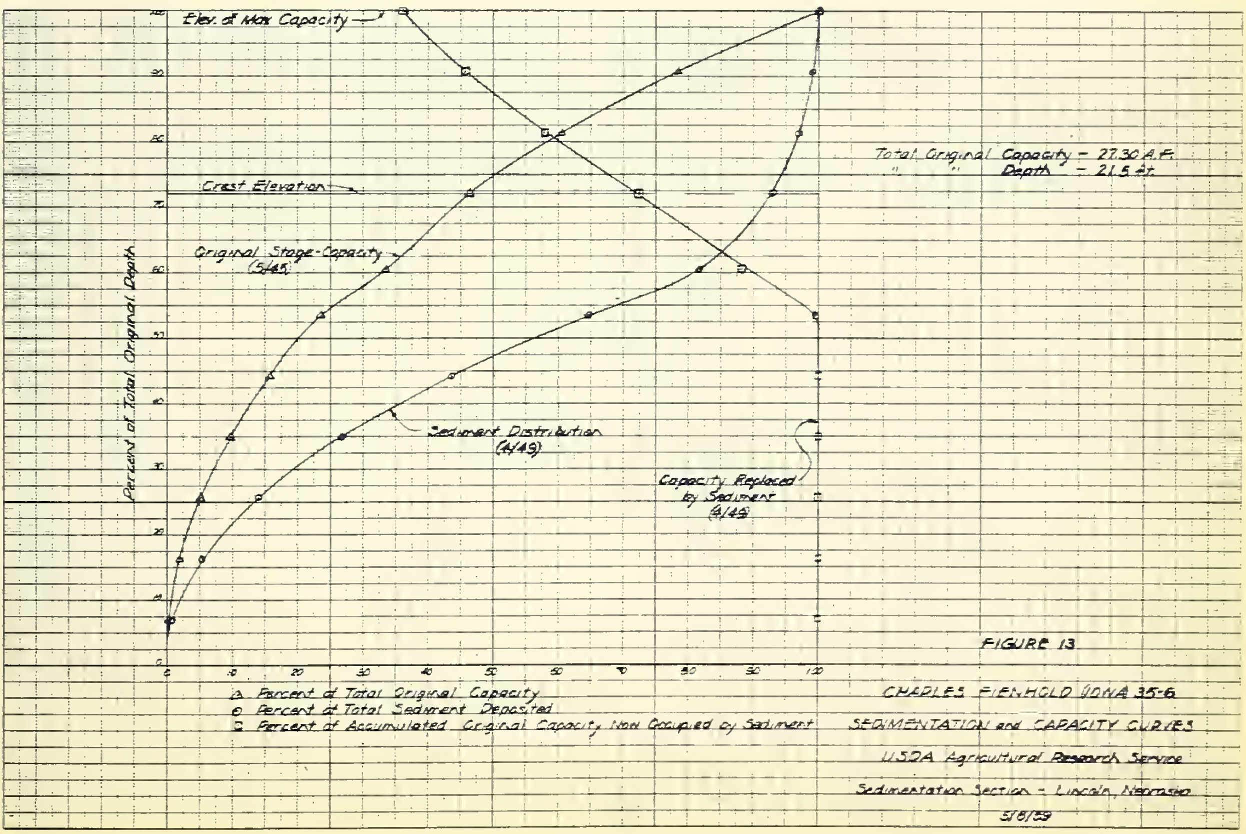


FIGURE 13

CHARLES FIENHOLD (IOWA) 35-6

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

5/8/59

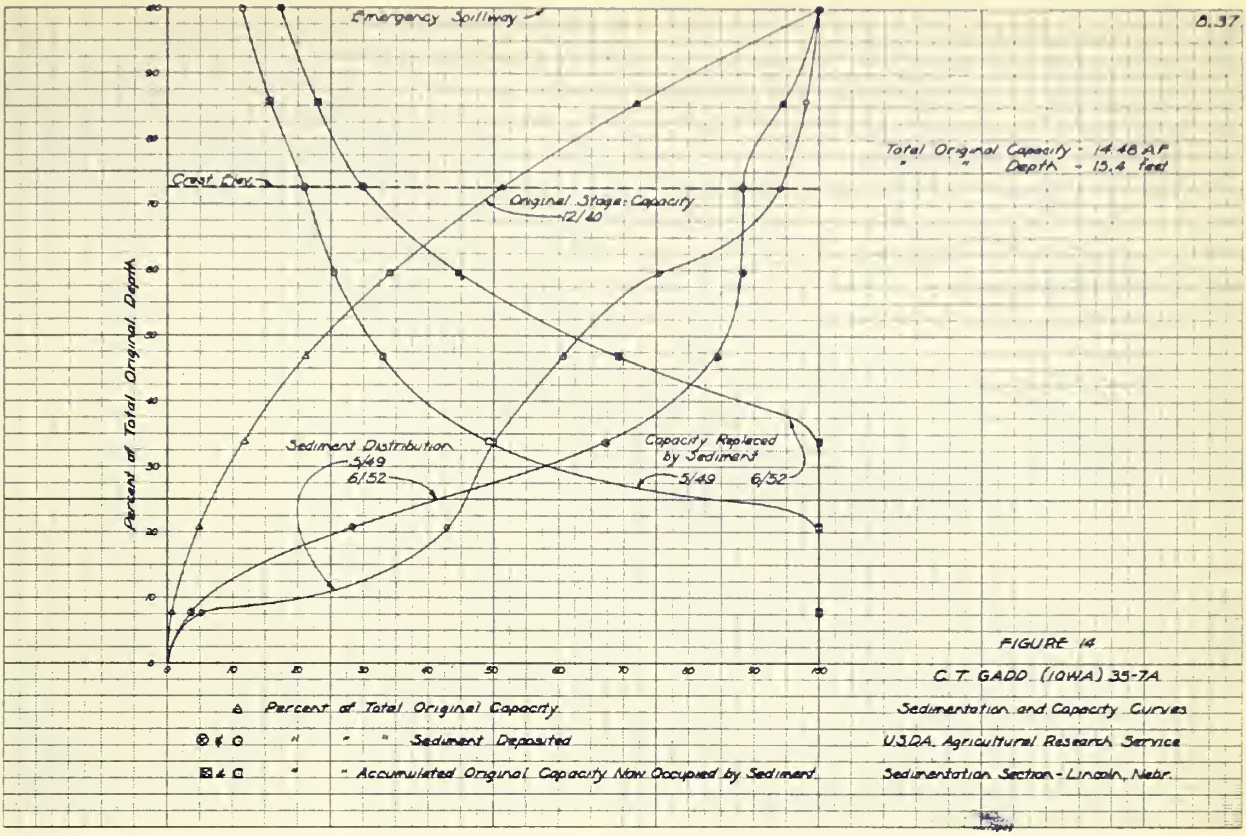


FIGURE 14

C. T. GADD (IOWA) 35-7A

Sedimentation and Capacity Curves

USDA. Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.

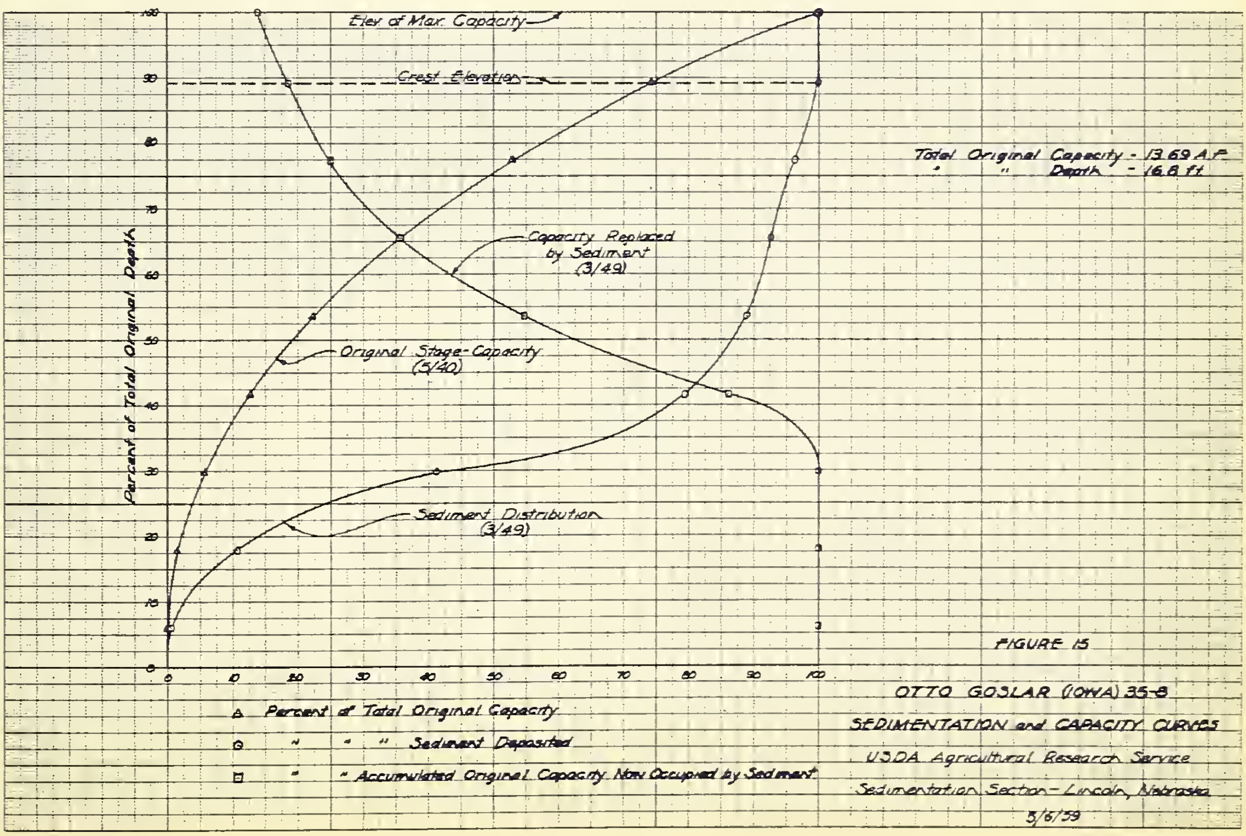


FIGURE 15

OTTO GOSLAR (IOWA) 35-8

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

3/6/59

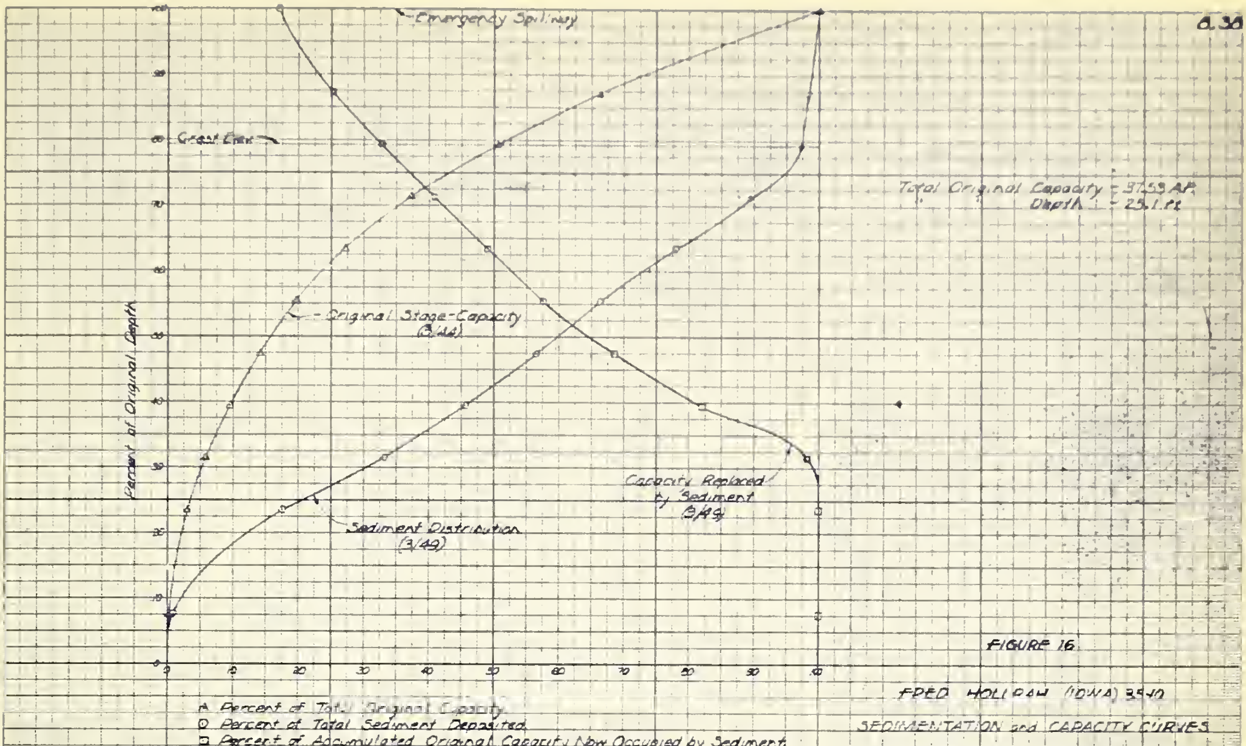


FIGURE 16

FRED HOLLPAW (IOWA) 35-10

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section - Lincoln, Nebraska

5/11/53

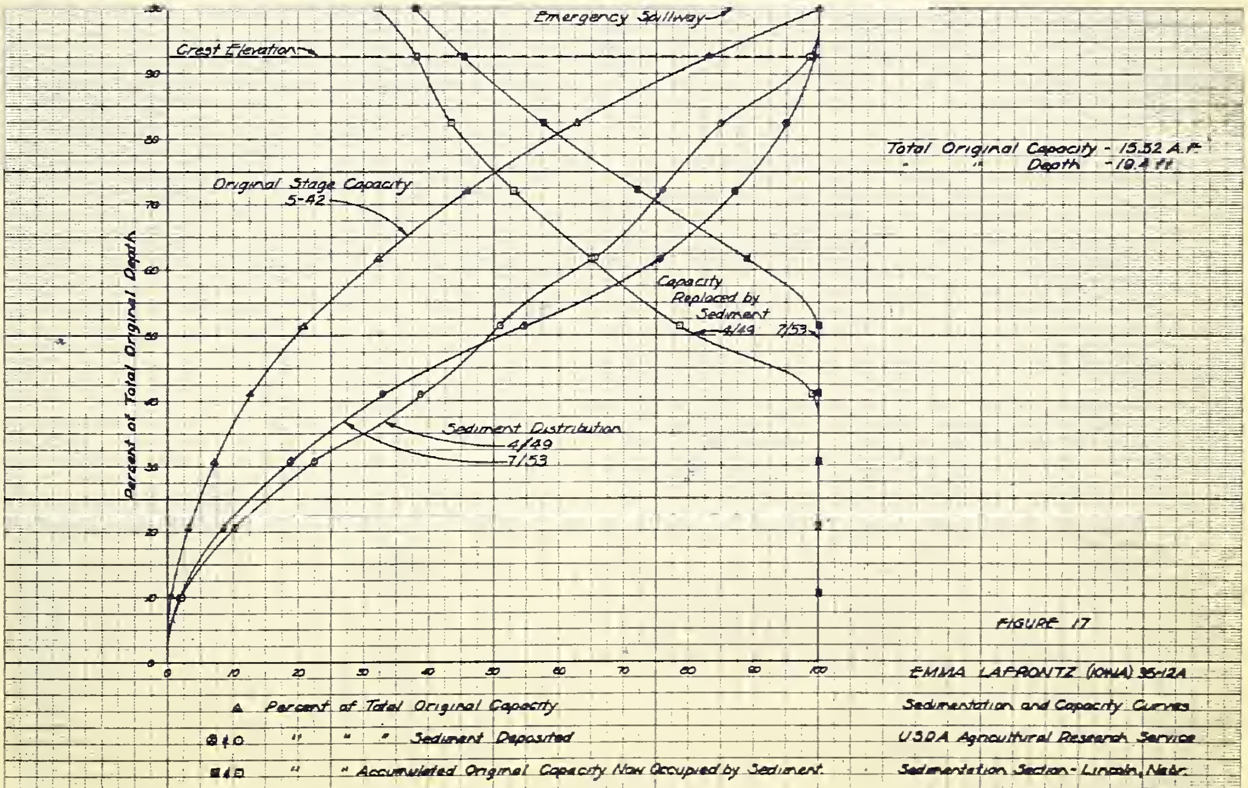


FIGURE 17

EMMA LAFRONTZ (IOWA) 35-12A

Sedimentation and Capacity Curves

USDA Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.

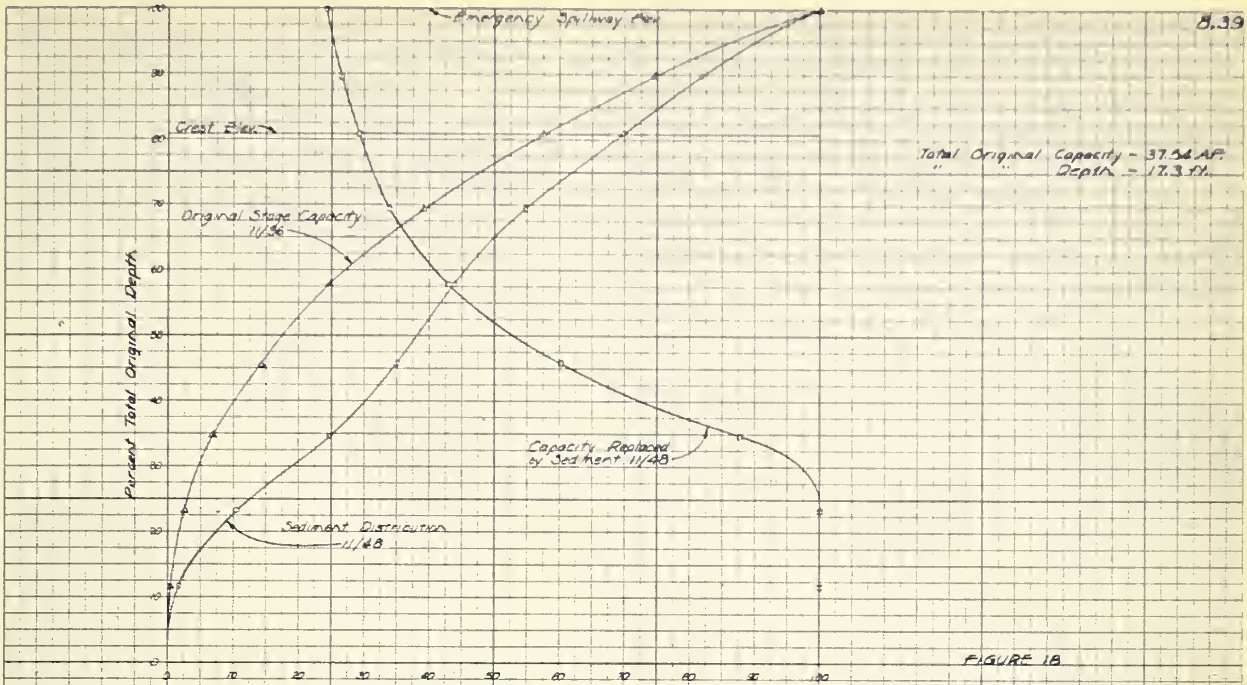


FIGURE 18

△ Percent of Total Original Capacity
○ Percent of Total Sediment Deposited
□ Percent of Accumulated Original Capacity Now Occupied by Sediment

JENSEN-O'NEIL (Nebraska) 35-13

SEDIMENTATION & CAPACITY CURVES

USDA-Agricultural Research Service

Sedimentation Sec. Lincoln Neb.
7-1-59

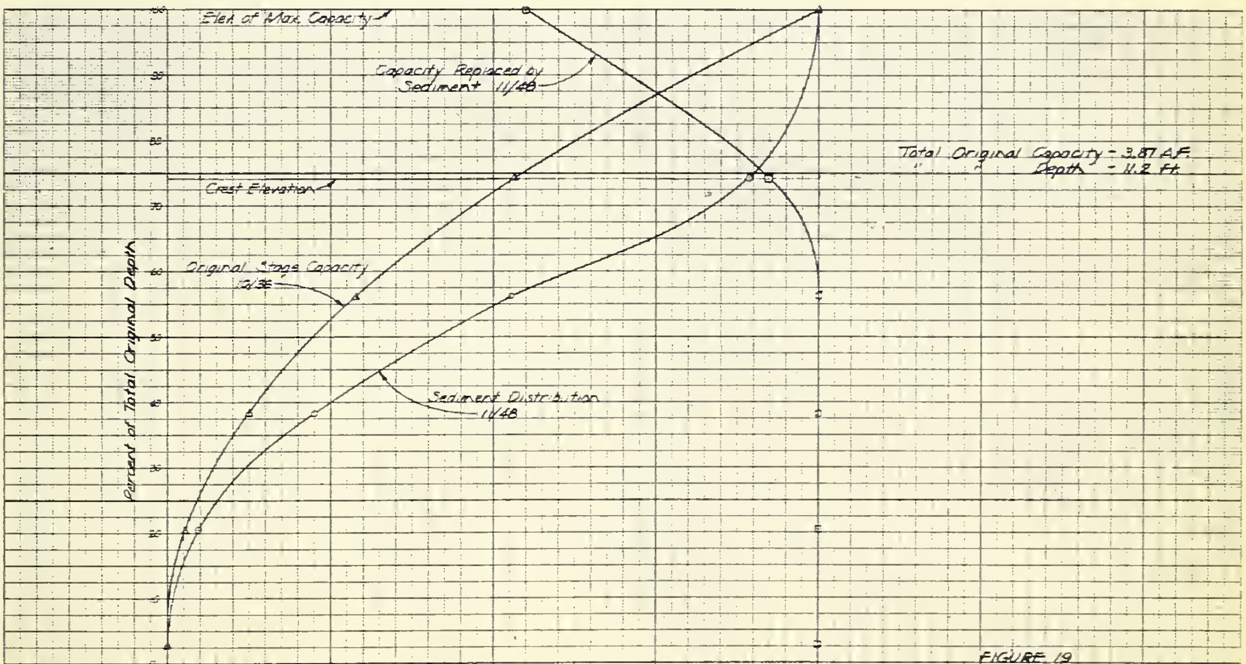


FIGURE 19

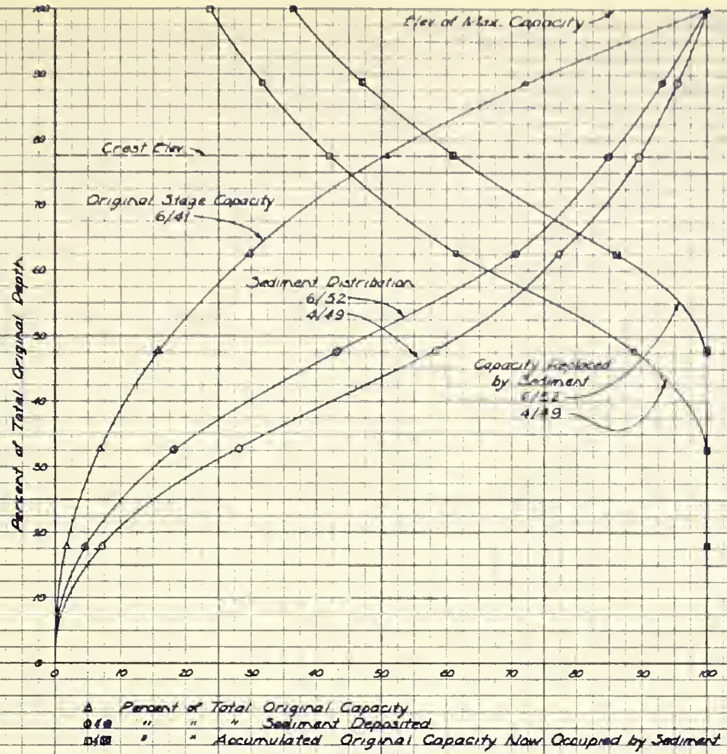
△ Percent of Total Original Capacity
○ Percent of Total Sediment Deposited
□ Percent of Accumulated Original Capacity Now Occupied by Sediment

PETERSON (Nebraska) 35-14

SEDIMENTATION & CAPACITY CURVES

USDA-Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.
7-8-59



Total Original Capacity - 11.23 A.F.
" " Depth - 13.4 Ft

FIGURE 20

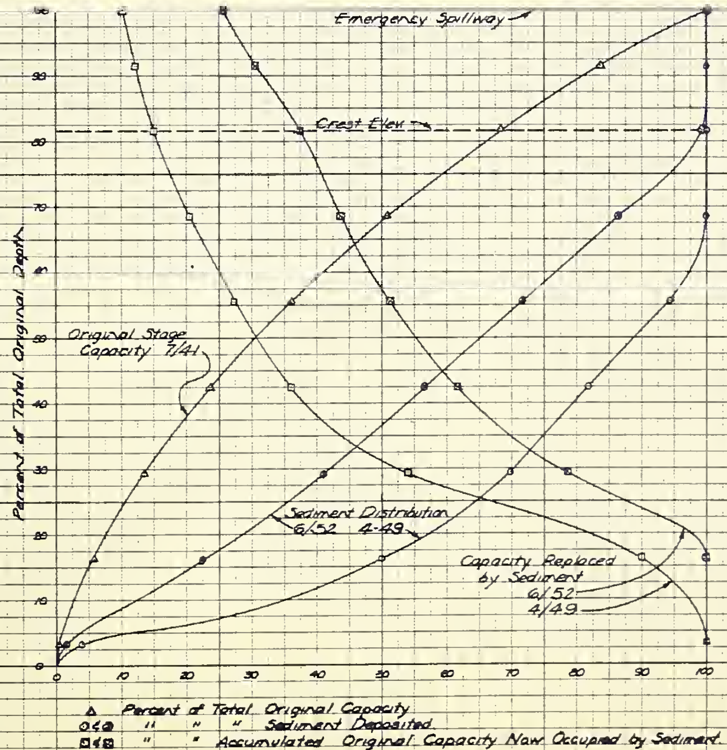
ALFRED LAGE (IOWA) 35-15A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

4/29/59



Total Original Capacity - 12.07 A.F.
" " Depth - 15.3 Ft.

FIGURE 21

HERMAN LAGE (IOWA) 35-16A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/13/59

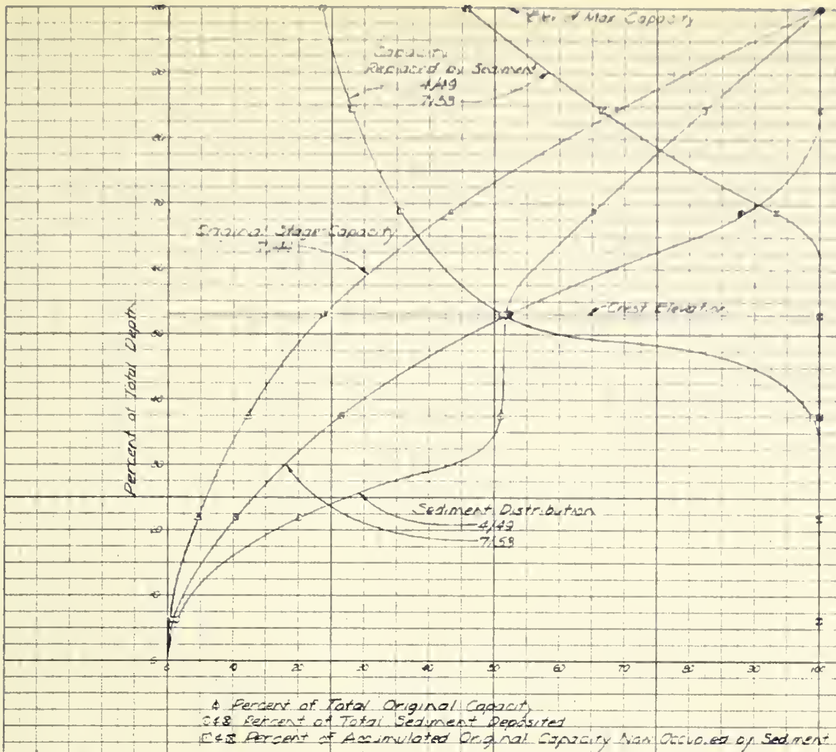


FIGURE 22

HOWARD MATTSON (IOWA) 35-17A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section - Lincoln, Nebr.

6/4/59

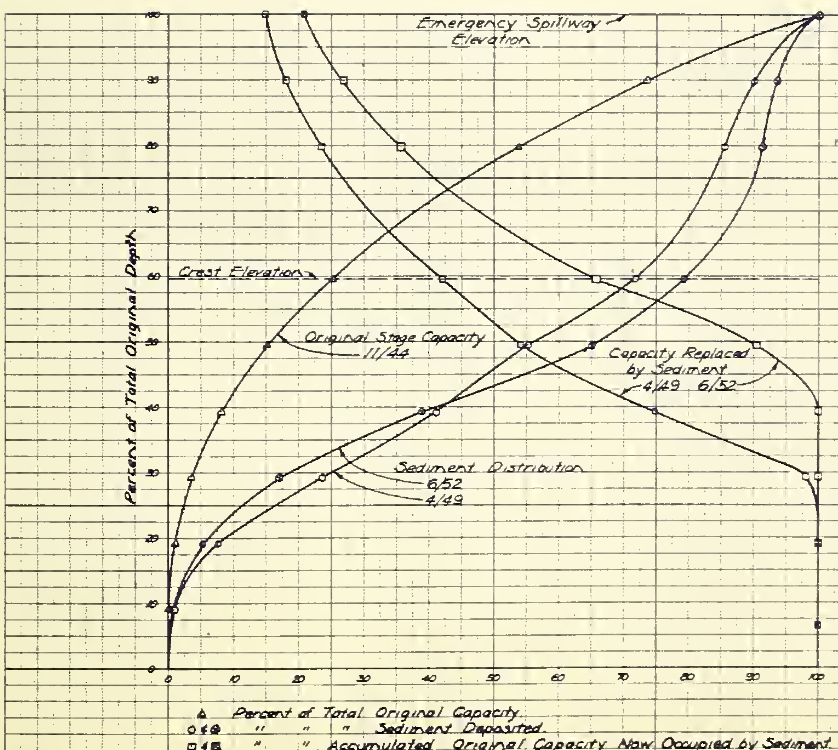


FIGURE 23

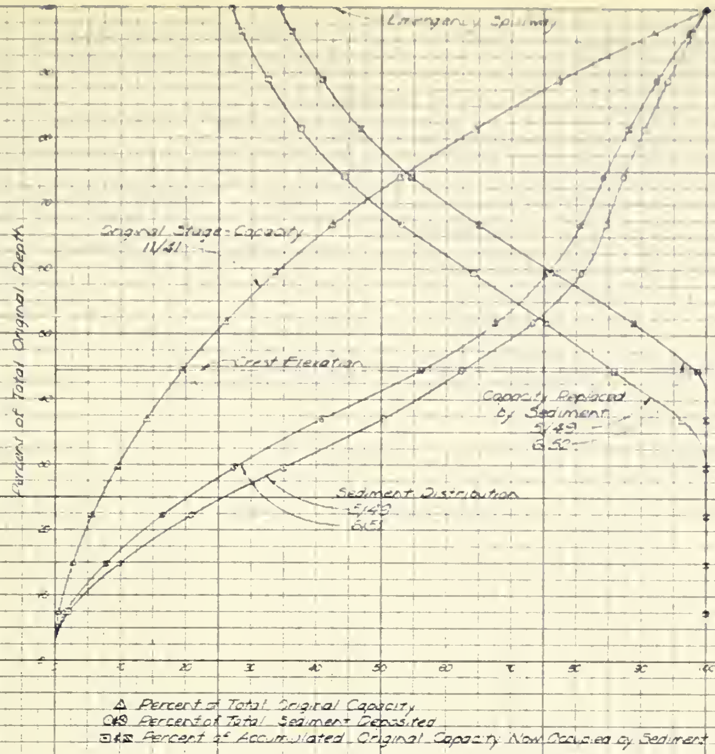
WILLIAM MEYER (IOWA) 35-18A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/59



Total Original Capacity - 13.84 A.F.
" " Depth - 13.3 ft.

FIGURE 24

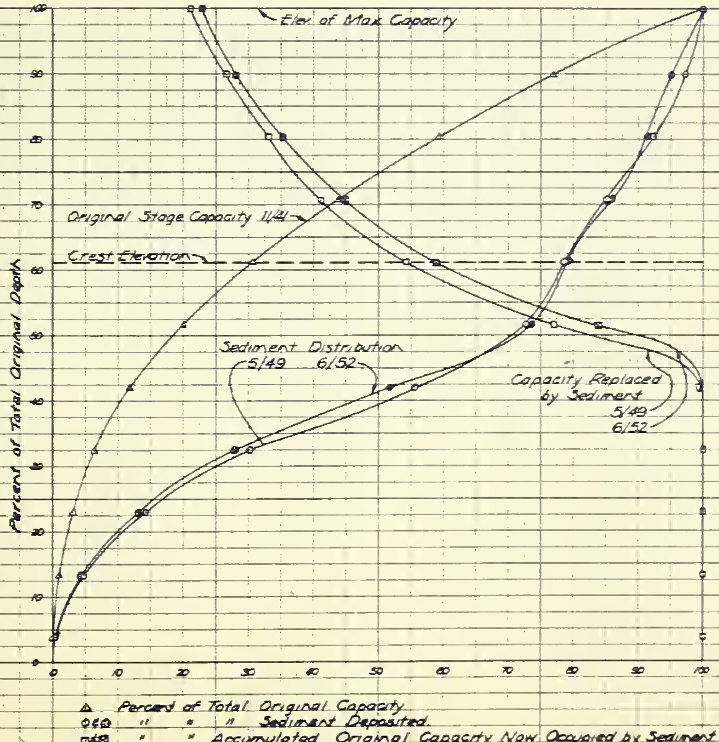
MILLER No 1 (IOWA) 35-19 A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section - Lincoln Nebr.

6/3/59



Total Original Capacity - 53.19 A.F.
" " Depth - 20.9 ft.

FIGURE 25

MAX MILLER No 5 (IOWA) 35-20A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/22/59

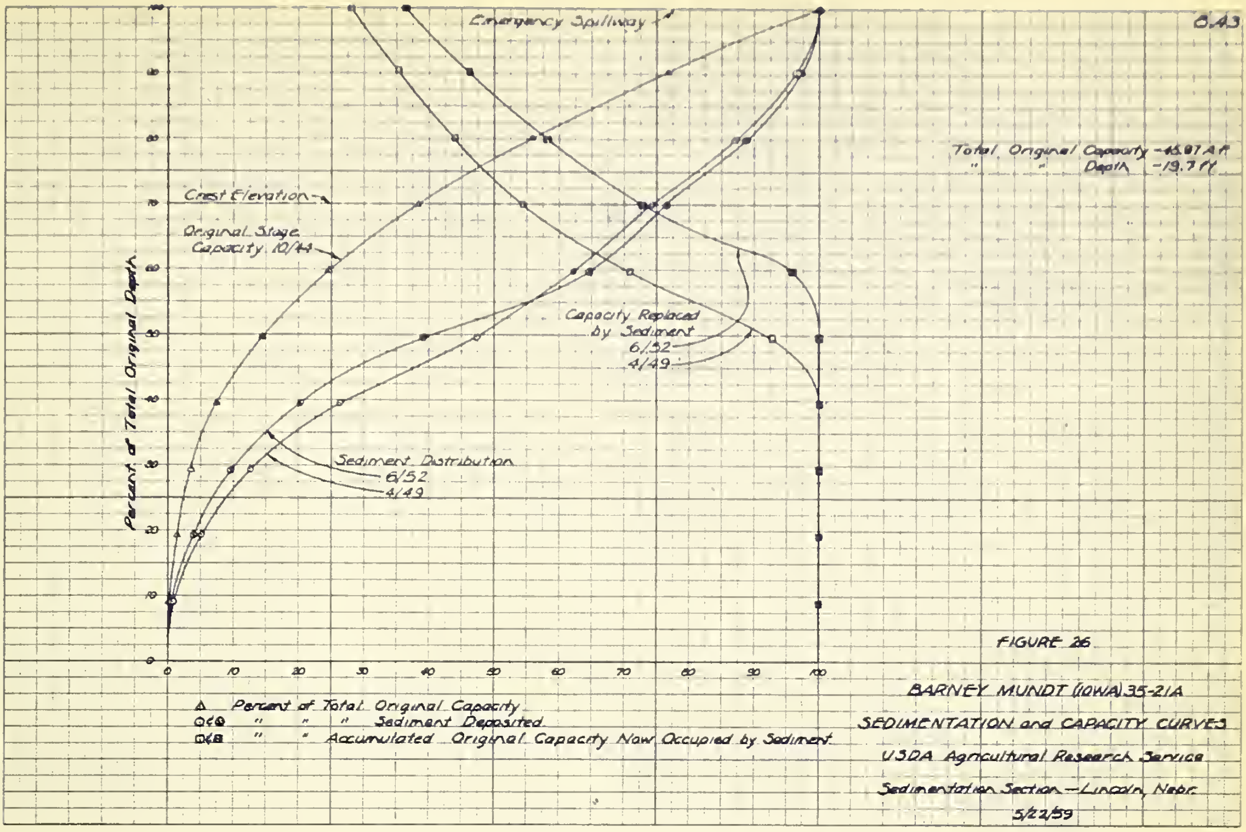


FIGURE 26

BARNEY MUNDT (IOWA) 35-21A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/22/59

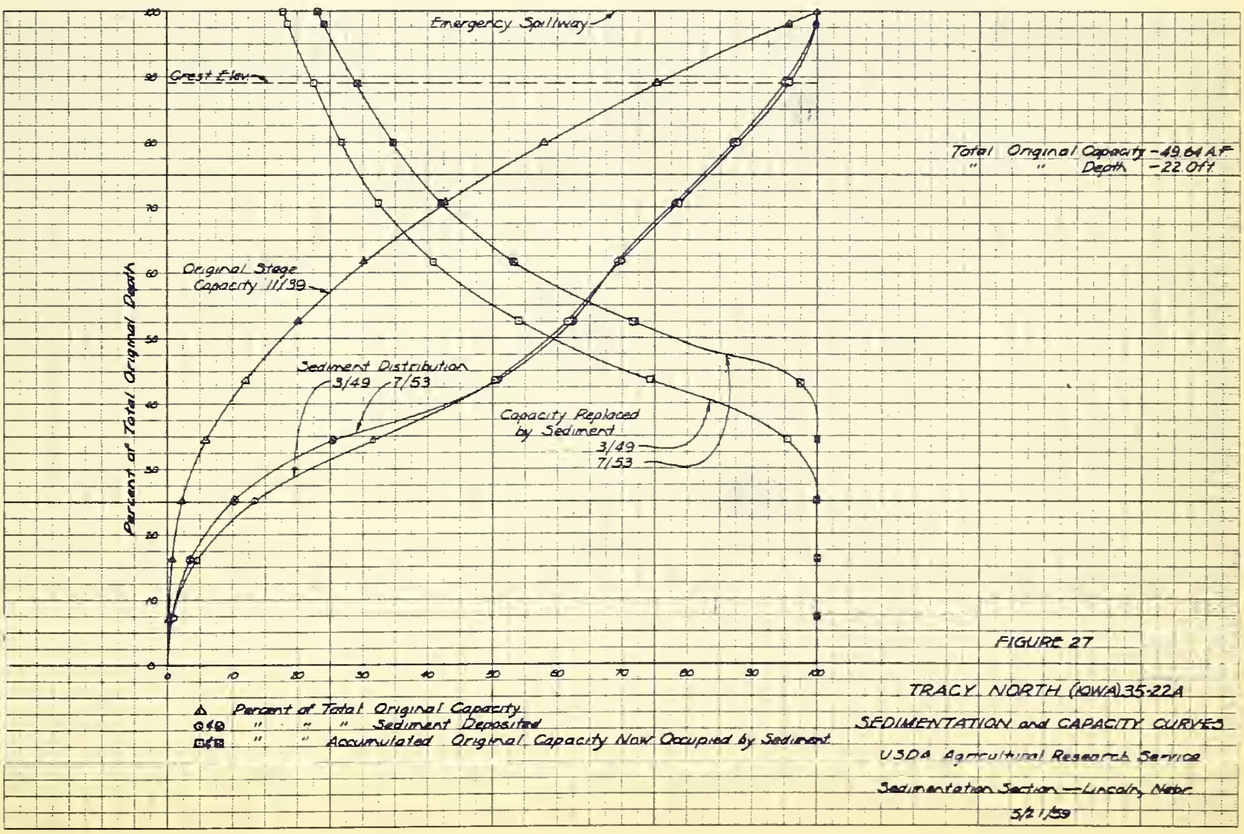


FIGURE 27

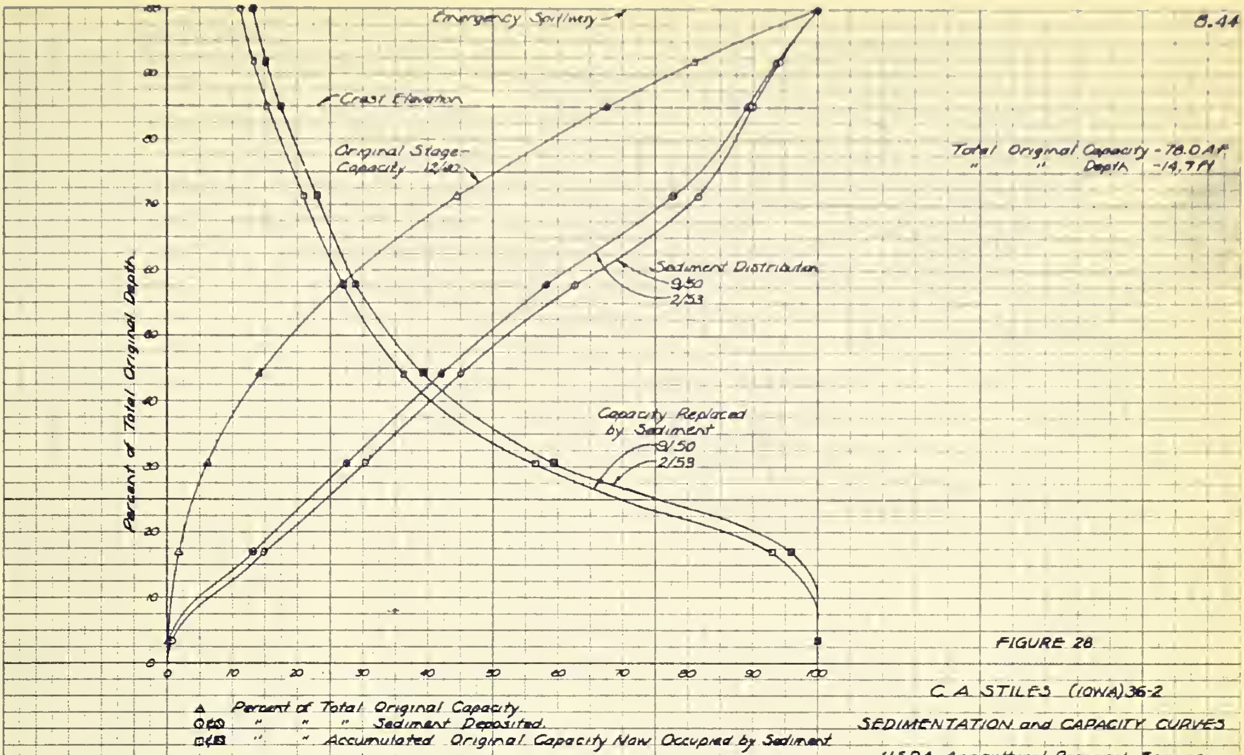
TRACY NORTH (IOWA) 35-22A

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

5/21/59



B.44

FIGURE 28

C.A. STILES (IOWA) 36-2

SEDIMENTATION and CAPACITY CURVES

USDA Agricultural Research Service

Sedimentation Section — Lincoln, Nebr.

7/8/59

△ Percent of Total Original Capacity.
○ " " " Sediment Deposited.
□ " " Accumulated Original Capacity Now Occupied by Sediment

GENERAL

The useful life of various types of reservoirs and ponds depends upon numerous sedimentation factors, including source of sediment, gross erosion, delivery rate, sediment yield, trap efficiency, sediment accumulation, sediment distribution, density of sediment, character of sediment, rate of storage depletion, etc. These factors depend on such things as precipitation, runoff, topography, soils, geology, land cover, reservoir and watershed size and shape, operating water level, and other physical and watershed characteristics. The sedimentation factors must be studied thoroughly and methods must be developed for predicting them and also for controlling them. This is vitally important in planning the design and in studying the feasibility of proposed reservoirs and ponds. Therefore, every opportunity is used to secure more facts and to develop criteria which will be helpful in these considerations.

During the past year the only general work in this regard has been to continue computations of reservoir sedimentation surveys completed prior to 1959. Plans for future activities and studies have been made to increase our knowledge in this field. Work with the Beach Erosion Board sediment density probe will be started next summer and should add considerably to our information on the density of sediment.

An application has been submitted to the University of Illinois for permission to use the Illiac, a digital computer, to speed up reservoir capacity and sediment volume computations. Mr. Verne Dvorak has also developed a procedure whereby cross-sectional areas can be computed and checked on statistical calculating machines in a fraction of the time formerly required. This will be submitted to you for approval and further dissemination. Both of these items should assist us materially in future studies.

In Illinois, we are cooperating with the Illinois State Water Survey and others who are currently making reservoir sedimentation surveys and the related analyses for predicting sediment yield and other factors. This work is being done on several portions of the Springfield plains. During the past year our cooperation has been limited to planning and consultations.

AN OVERALL SUMMARY OF SIGNIFICANT FINDINGS

1--The Medicine Creek Watershed is a 690 square mile drainage area in southwestern Nebraska in which information was collected on precipitation, runoff, gully erosion, sediment load, land use, topography and soils for an eight year period (1951-58).

Statistical tests show that precipitation during the period 1951-58 was not representative of the long term. In this period the average yearly precipitation was 18.82 inches, as compared with the long term average of 21.36 inches. In 1951, 31.61 inches of rainfall were recorded; in the next five years, the average was only 14.55 inches; but in the two remaining years of the project, it was close to the long term average.

The runoff for 1951 was the large portion of the total for the 1951-58 period. In that year, Dry and Brushy Creeks (intermittent streams) had 63 and 35 per cent, respectively, of their eight year totals. Meanwhile, Fox Creek, and Medicine Creek at Maywood and also above Harry Strunk Lake (perennial streams) had 27, 17 and 23 per cent, respectively, of their period totals.

Most of the suspended sediment transported out of the Medicine Creek subwatersheds during the period 1951-58 resulted from a few large storms in 1951, as shown.

Subwatershed	Percent of 1951-58 total suspended sediment transported in 1951	Number of selected large storms in 1951	Percent of total period sediment transported by the selected storms
Dry	73	1	20
Fox	91	2	39
Brushy	56	2	25
Medicine Creek at Maywood	60	2	18
Medicine Creek above Harry Strunk Lake	72	4	45

Statistical tests show that the daily suspended sediment rating curves for Dry, Brushy, and Mitchell Creeks have highly significant correlation coefficients. The tests further indicate significant differences in the sediment rating relationships by months and seasons for Brushy and Mitchell Creeks.

The long term suspended sediment yields were calculated using the three different methods shown in the accompanying table. In these computations, no adjustments were made to make the data more representative.

Suspended Sediment Yield in
Acre-Feet per Square Mile per Year

Creek	100 Year Period: Flow-Duration, Daily Sediment Load Method	100 Year Period: Frequency of Annual Runoff with Annual Runoff and Suspended Load Relationships	Suspended Sediment Sampling 1951-58
Dry	2.43	1.56	1.835
Brushy	1.21	0.60	0.576
Mitchell	0.50	0.61	0.362

The flow-duration, daily load method gives higher yields than those computed directly from the samples because the flow-duration curves are prepared by extending a portion of the high runoffs to obtain 100 years of flow. Furthermore, the sediment rating curve shows that an increase in runoff results in an increasing rate of transported sediment.

The flow duration method usually provides higher values than the annual method because the large individual storms which produce the greater quantities of runoff and sediment do not lose their direct effects as when averaged in the annual computations.

2--A study was recently completed of the sediment distribution in 23 small conservation reservoirs in the Missouri Basin loess hills. This is an area of western Iowa, eastern Nebraska, and northwestern Missouri. The characteristics of these reservoirs are similar to those of floodwater retarding structures being built in the area by the Soil Conservation Service (P.L. 566) and the findings are considered directly applicable. Considerable data were obtained on these small ponds and reservoirs, and Stage-Capacity, Capacity Replaced by Sediment, and Sediment Distribution curves were drawn for each.

After making numerous graphical analyses, the multiple regression approach was used to develop a precedure whereby the elevation can be determined to which sediment will accumulate immediately upstream from a small floodwater retarding structure. Assuming that the total initial reservoir capacity has been established for a proposed structure and that the sediment

deposition quantities and specific weight of sediment for a given design period has been determined, the following equation can be used:

$$Y = 22.6 + 0.886D - 81.2n - 0.175C + 0.494w$$

where Y = per cent of original reservoir depth filled with sediment
D = total original storage depletion in per cent
n = slope of line on logarithmic paper where the original reservoir depths (ordinates) are plotted versus original reservoir capacities (abscissas)
C = total remaining storage capacity
w = sediment sample volume weight

From this equation, the per cent of original reservoir depth can be readily established below which the initial capacity will be completely filled with sediment. This is the elevation to which sediment will accumulate immediately upstream from the dam and is, therefore, a guide to the minimum elevation for the principal spillway.

In addition to the above, a method was developed for drawing a Capacity Replaced by Sediment Curve. When this is used with the Original Stage Capacity Curve, the sediment distribution can be computed and such a curve drawn. This shows the amount of sediment deposited throughout the original reservoir depth. This can be repeated for various percentages of storage depletion in the reservoir.

It should be emphasized that this first study and the resulting material applies to small floodwater retarding structures in the Missouri Basin loess hills only. Additional analyses are planned or under way to study relationships applicable in other areas.

PUBLICATIONS

"Sediment Distribution in Soil Conservation Service Floodwater Retarding Structures--Missouri Basin Loess Hills." H. G. Heinemann. Report presented at the ARS-SCS Sedimentation Workshop, University, Mississippi. Sept. 1959.

"Sedimentation Section Research Activities--Lincoln, Nebraska." H. G. Heinemann. Report presented at the ARS-SCS Engineering Research Meeting, Milwaukee, Wisconsin. January, 1959.

"Status of Medicine Creek Long Term Sediment Yield Determinations." Verne I. Dvorak. Report presented at the ARS-SCS Sedimentation Workshop, University, Mississippi. Sept. 1959.

The first item listed above is now being prepared for publication as an ARS Report. A draft of a report on our use of the Bureau of Reclamation Radioisotope Sediment Densitometer was submitted for approval as a Research Report. Two articles were also prepared for the quarterly reports of "Progress in Soil and Water Conservation Research."

PROJECT NEEDS

Our present program consisting of data analyses and the collection of special data is worthwhile and well oriented. It is believed that this Project had several noteworthy accomplishments during the year. We are also making some progress on our computations backlog for reservoirs and ponds surveyed several years ago.

It is felt, however, that we need to get started on trap efficiency studies. Reservoirs and ponds need to be located (having a wide range in conditions), selections made, sedimentation surveys completed (including volume weight determinations), and sediment measurements started on incoming and outgoing flows. This will take some time, and after completion of this work, a period of time must also elapse before resurveying. Hydrologic and watershed characteristics can be measured and inventoried between surveys. This study should be started soon, because a period of <u>at least</u> five years is needed after the initial priorities (including the first sedimentation surveys) are completed.

A careful review also needs to be made of the trap efficiency information and data furnished to us during the past several years by the Soil Conservation Service. This is the work being done for the SCS by the Geological Survey. Just a casual review reveals apparent shortcomings, omissions, etc. These deficiencies need to be investigated further and corrected before too much additional time lapses and personnel are transferred, etc.

This Trap Efficiency Project should be supported with the addition of another full time professional employee and also another full time engineering aid. The presently assigned personnel have numerous projects and activities to concentrate on that are of equal importance.

We have a 1956 Chevrolet sedan which is in a good state of repair. It recorded a total of 31,400 miles as of January 1, 1960. It is adequate for our present needs.

The following table gives information on our office machinery:

Office Machine	Age (yrs)	Condition	Need for Replacement	Manufacturer
Calculator	1	Excellent	None	Monroe (statistical)
Calculator	12	Good	None	Friden
Calculator	20+	Good	XX	Friden
Calculator	20+	Good	None	Monroe - Portable
Adding	7	Good	None	Remington Rand
Adding	Unknown	Fair	None	Underwood
Typewriter	Unknown	Fair	XX	Royal
Typewriter	Unknown	Fair	XX	Corona - Portable

We have need for another statistical calculating machine. They are such time savers in our work. Our present statistical calculating machine is being used most of the time, and another one borrowed from the Cooperative Water Yield Procedures Study Group whenever they are not using all of their machines. It is, therefore, recommended that the oldest Friden marked XX and our two typewriters be traded in on a new calculating machine.

Our Secretary uses a typewriter belonging to the Cooperative Water Yield Procedures Study Group. This is a very good machine and the arrangement is satisfactory to us.

MISCELLANEOUS ITEMS

This Project represents the Agricultural Research Service on the Technical Committee, Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources. This is the cooperative sedimentation project at the St. Anthony Falls Hydraulic Laboratory in Minneapolis. One of our main assignments here is to develop a device that will automatically measure the suspended sediment moving past a given location. During the year, Report AA, "Federal Inter-Agency Sedimentation Instruments and Reports," May 1959, was published. A draft was also prepared of Report No. 13, "The Single-Stage Sampler for Suspended Sediments."

Following is a tabulation of the planning conferences and meetings attended during 1959:

Date	Location	Purpose
Jan. 15, 16	Minneapolis, Minn.	Technical Committee
Jan. 19 - 22	Milwaukee, Wisc.	ARS-SCS Engineering Research Meeting
Jan. 22, 23	Urbana, Illinois	Planning Conference -- Illinois State Water Survey
Feb. 5	Topeka, Kansas	Sabetha Project Cooperators' Meeting
March 2	Sabetha, Kansas	Relocation of rain gages--Sabetha Proj.
Mar. 30, 31	Minneapolis, Minn.	Technical Committee
April 21 - 23	Des Moines--Ames, Ia.	Sediment Distribution Project
April 28 - May 1	Denison & Sioux City, Iowa	Sediment Distribution Project
May 11	Hastings, Nebr.	Sedimentation work
July 10	Lincoln, Nebr.	Statistical Review--Sed. Distrib. Proj.
July 29	Lincoln, Nebr.	Project Review--Bill Pate
Sept. 15 - 19	University, Miss.	ARS-SCS Sedimentation Workshop
Sept. 21 - 23	Minneapolis, Minn.	Technical Committee
Nov. 18 - 20	Minneapolis, Minn.	Workshop (Stenos & Clerks)
Dec. 15 - 17	Lincoln, Nebr.	Review of Sed. Distrib. Report
Dec. 22	Lincoln, Nebr.	Special Fund - Univ. of Nebraska

There were several conferences during the year with the Soil Conservation Service and the U. S. Geological Survey in connection with the Medicine Creek, Sabetha, and Whitehead Projects. We assisted the Soil Conservation Service with a determination of an approximate trap efficiency value for the Plattsmouth, Nebraska Project. In addition, we prepared for the SCS a write-up and exhibits on our sedimentation survey procedures, and formulas and methods of making the remaining capacity and sediment volume computations. This included details in regard to adjustments and the computations involved in a set of sedimentation information curves.

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